Fig. 13.—Wild Geranium lea
blade divided.

. 12.—Leaves of the pear-tree.
, petiole.
, blade, or lamina.

First Steps in Scientific Knowledge

Paul Bert, Josephine Clayton Bert, William H. Greene

FIRST STEPS

IN

SCIENTIFIC KNOWLEDGE.

COMPLETE IN SEVEN PARTS.

I. *ANIMALS.*—II. *PLANTS.*—III. *STONES AND ROCKS.*
IV. *PHYSICS.*—V. *CHEMISTRY.*—VI. *ANIMAL PHYSIOLOGY.*—VII. *VEGETABLE PHYSIOLOGY.*

BY

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PART I.

NATURAL HISTORY OF ANIMALS.

PREFACE.

Before the English translation of the "First Steps in Scientific Knowledge" appeared, five hundred thousand copies of the original had been sold in France within three years. Immediately after the appearance of the first English edition a second was called for, and the American publishers feel confident that the success of the American edition will not be less than that of the foreign.

The American editor has made in the excellent translation of Madame Bert only such changes and additions as were necessary to Americanize the book, and adapt it to the requirements of public and private schools as well as to home instruction in this country.

The Natural History has been slightly enlarged by the introduction of several American species, omitted in the original and in the English edition, and a few inaccuracies concerning other species met with in the United States have been corrected.

TABLE OF CONTENTS.

NATURAL HISTORY.

I.—ANIMALS.

DIVISIONS OF THE ANIMAL KINGDOM.

1. Classification.—The study we intend to pursue together is *Natural History*, and we will begin with the most interesting part of this science, and that with which you are already best acquainted,—namely, the natural history of ANIMALS.

ANIMALS, I am sure, interest you more than *plants*, and much more than *stones*. For *animals* grow, and move about; they feel, and show that they have will; they live and they die. *Plants* also live, and grow, and die; but they never move out of their place, and they feel neither blows nor caresses. As for *stones*, they do not move about, nor do they die, and they remain forever unchanged, if nothing displaces or alters them.

You already knew all this, and you are, moreover, aware that *animals* are exceedingly varied in shape as well as in size. A whale, a fly, an elephant, a sparrow, a tiger, a snail, a beetle, a spider, an earth-worm, are animals that widely differ from one another, and you have all certainly heard about them. Their history no doubt interests you, and you like to learn what services they may be able to yield us, or with what dangers they menace mankind.

This is not all: you are also aware that we ourselves in many respects resemble some animals, especially as regards our internal construction. You know that you have a *heart* beating in your breast, that you have *lungs* with which you

breathe, a *stomach* and *intestines* that digest the food, *eyes* that see, and *ears* that hear. And if you have ever happened to look at a butcher's stall, or to have seen any one prepare a rabbit for cooking, you know that the ox, the sheep, the pig, the rabbit, and many other animals have an internal arrangement more or less similar to our own. Thus in studying animals pretty closely we study ourselves, and you can all easily conceive how very interesting this must be.

But the first difficulty that presents itself is, to select a part of our wide and interesting subject with which to begin; and I have no doubt you would feel yourselves somewhat at a loss were you left alone to decide this. In the course of the years since you were quite little children, you have learned a great many things about animals; your reading-books, story-books, and picture-books have given you useful and attractive information on the same subject.

You all know, as well as I do, that the *lion* is a great African animal that kills and devours oxen and even men, and that the *ostrich* is a large bird that lives in the African desert; and you may have pretty correct notions about *sharks*, *rattlesnakes*, *humming-birds*, *crocodiles*, *camels*, and so on. Now that you have grown older, you must give up studying all these things at random, and arrange all your notions of animals in proper order, for this is the only way to remember what we learn, and to be able to profit by it. We shall complete our knowledge as we go along.

For this purpose we must not study animals one after another, without method. We must follow out what naturalists call a *classification*, and group together the animals that have the greatest resemblance to one another, so as to avoid having to repeat for each of them that which they all have in common. Thus, we shall put all the *birds* side by side, and say once for all that they have a beak, wings, and feathers.

But it is no easy matter to make a good classification. One must know exactly in what respects animals resemble one another, also what differences exist between them, and this requires attentive examination without and within.

2. Animals that have Bones and Animals that have no Bones.—Can you tell me what differences there are between a horse and a fly? I see the question makes you laugh. But that is not a sufficient answer; try to tell me.—"Well, a horse is a very large animal, and a fly is very small."—That's true; but here is a wood-cut which shows you a fly magnified, and another in which a horse is represented very small. You would never take the one for the other, notwithstanding the size. Do you see nothing else?—"A fly has *wings*, and a horse has none."—Ah! that is better: but suppose some accident had deprived the poor fly of its wings, would it then be quite like a horse? Of course not. What other difference could you find?—"A horse is covered with hair, and a fly has none."—Are you sure of that? Catch a fly and look at it with this magnifying-glass. See, its body is covered with hairs. True, they are very small, but yet they exist. I see you have something to say.—"A fly has *six* legs, and a horse has but *four*."—Ah! that's a good observation, and will hereafter prove useful. But suppose the fly had lost, along with its wings, two of its legs: what then? Can you find no other difference? No, say you? Ah! there are many nevertheless, and very great ones too.

Can we crush a fly? Oh, yes, very easily, and nothing remains but the external parts,—the skin, the legs, and the wings. Could we do the same with a horse? I know very well that we have not in ourselves sufficient strength. But suppose a house were to fall on it, would it thereby be crushed and reduced to a sort of pulp, as would happen with the fly? No; and why? *Because the horse has inside its body hard parts, bones that cannot be crushed; whilst the fly has none, not even very tiny ones.* The horse, then, is an ANIMAL THAT HAS BONES, its body is supported by a SKELETON, as we call the whole of the bony frame; the fly is an ANIMAL THAT HAS NO BONES.

Another difference of no less importance. Were a fly to be pricked, a drop of *colorless liquid* would come from the wound. But if a horse be pricked, what will flow from his

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What fundamental difference is there between a horse and a fly? In what other respects do they differ?

wound? Ah! I see you all know that: *blood!* Yes, blood, a red liquid, very curious to examine, as we will do hereafter. *So animals that have bones have also real blood, red blood.* This is another important point.

3. Vertebrates.—Besides the horse, do you know any other animals having a skeleton and red blood?—"Oh, yes! the *cat*, the *dog*, the *pig*, the *ox*, the *rat*, the *hare*."—You might add yourself to the list, don't you think so? Do you feel offended at being counted among animals? Yet it is quite correct to do so: we eat, we breathe, we are born, we die, in the same way as animals do, and we are fashioned just like animals with blood and bones. This in no wise diminishes our moral superiority, however; for though we live and breathe no better than animals, we think very much more and better than they. So there is nothing shocking or offensive in the fact.

But let us return to our subject. I must say, you have displayed but little imagination in searching out your examples. All the animals you have mentioned are very like one another, for they are all four-footed, and are clad in hair, or fur. They are *hair-* or *fur-clad quadrupeds.* Do you remember any others that have blood and bones?—"Yes, the *birds*."—Very well. Any others?—"*Fishes.*"—Any others still?—"Serpents, frogs, lizards."—Quite right. And what general name is given to these three last?—"*Reptiles.*"—That's right. We shall come back to this in a little while.

So, QUADRUPEDS B (Fig. 1), BIRDS C, REPTILES D, FISHES E, *may be classed together as having bones and red blood.* They all come under the general name of VERTEBRATA, because among the bones of the body a certain number, called *vertebræ*, form the spine or backbone, from F to G, whence the name of *vertebral* or *spinal column* given to the whole series of those vertebræ. You may easily feel them under the skin, all along the back. Some vertebrates have no *limbs*, like serpents D, the vertebral or spinal column, together with

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In what animals do we find red blood? Name some animals formed with bones and having red blood and in some respects resembling a horse. Name some other animals quite different from the horse, but that resemble one another in having bones and blood. Under what common name are all these animals ranked? Why? What peculiarities does the skeleton of the serpent present?

the head (or, properly speaking, with the *skull*, a name given to the bones of the head taken as a whole), forming, in their

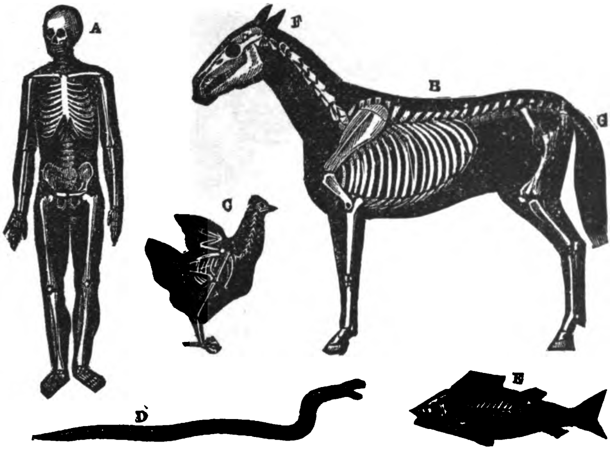

Fig. 1.—*Vertebrate* animals, that is to say, animals that have a spine or backbone FG, called *vertebrates*. A, man; B, quadruped; C, bird; D, reptile; E, fish.

case, all the skeleton; but almost all vertebrates have limbs. We will continue this part of our study some other time.

4. Annulata.—We will now pass on to those animals that have *neither bones nor red blood*, and that are called *invertebrates*, to distinguish them from the others.

We have already spoken about the *fly*, that has two wings and six feet. Do you know any other creature you might class along with it? Shall we say a beetle (Fig. 2)? Yes, evidently. How many wings has a beetle?—"*Four*."—How many feet?—"*Six*."—Very good. Mention another.—"A *butterfly* (Fig. 3).—It has also four wings and *six* feet."—"*A dragon-fly* (Fig. 4) has also four wings and *six* feet."—Quite right. That's enough for the present. *All these six-footed creatures are called* Insects.

What name is given to animals that have neither bones nor red blood? Why? Name some animals with six feet. What general name is given to animals with six feet?

Now let us catch a SPIDER (Fig. 5). It is very like an insect, but it runs upon *eight* feet.

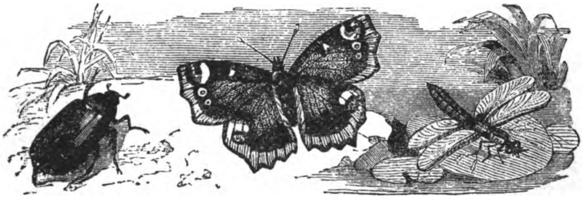

FIG. 2.—Beetle (insect), 6 feet. **FIG. 3.—Butterfly (insect), 6 feet.** **FIG. 4.—Dragon-fly (insect), 6 feet.**

This MILLEPED (Fig. 6) has at least twenty pairs of feet. If you look closely at all these animals, you will see that their bodies are composed of a series of RINGS strung together as it were, and working upon one another: they are said to be

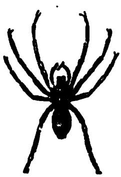

FIG. 5.—Spider, 8 feet.

FIG. 6.—Milleped, 20 pairs of feet.

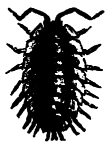

FIG. 7.—Wood-louse (crustacean).

articulated the one on the other. The *wood-louse* (Fig. 7) is also composed of a succession of rings.

The *crayfish* (Fig. 8), also, belongs to this group, but the rings that form its body are hard and crusty. It is therefore called a CRUSTACEAN (from the Latin *crusta*, a crust).

Here, now, is an *earth-worm* (Fig. 9), and here a *leech* (Fig. 10). They also have rings; but the head is not distinct from the body, neither have they feet; their skin is not

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What insect-like animals have eight feet? To what group do the milleped and the wood-louse belong? The crayfish? To what group do the earth-worm and the leech belong?

leathery like that of insects, nor stony and hard like that of a crayfish. They come under the general name of *Worms.*

Fig. 8. — Fresh-water Crayfish (crustacean).

Fig. 9.—Earth-worm (worm).

Fig. 10. Leech (worm).

Insects, *Spiders*, *Millepeds*, *Crustaceans*, and *Worms* are often designated by the general name of ANNULATA (from the Latin *annulus*, ring), because their bodies all seem to be composed of *rings*.

5. Mollusks.—Look at this *slug* (Fig. 11); it is quite naked, soft, and pulpy; and at this *snail* (Fig. 12), which is quite as naked and pulpy, although it has been clever enough to make for itself a *shell* that protects it, and wherein it finds

Fig. 11. — Slug (mollusk).

Fig. 12. — Snail (mollusk).

Fig. 13. — Mussel (mollusk).

shelter; see this *mussel* (Fig. 13), whose body is protected between two shells. *In these animals no traces of ring-shaped divisions are to be found: therefore they are not annulates. They have neither bones nor red blood: so they cannot be vertebrates.* The name given to them is MOLLUSKS.

6. Radiates.—Lastly, here are two illustrations. The one represents an animal which is very common on the sea-shore, and which bears the characteristic name of *star-fish* (Fig. 14).

Enumerate these different groups. What common name is sometimes given to them? What are the characteristics that distinguish snails, etc., from annulates and vertebrates? By what name are they designated?

The other (Fig. 15) is a much enlarged picture of a tiny creature that lives in colonies formed by countless numbers of little beings similar to the one figured here; these minute animals, called *polypi*, form around themselves a sort of slimy stony sheath, and the union of all those sheaths constitutes what is called a *polypary;* these polyparies often attain great dimensions, and form rocks, reefs, and even islands; coral and sponges are produced by polypi. These animals, although, as we shall see later, belonging to two widely different groups, have a central mouth, and so differ from all those which we have hitherto considered; as the body is produced into a series of rays which surround this mouth, the term *Radiates* is often applied to these similarly-constructed animals.

Fig. 14.—Star-fish.

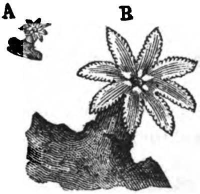

Fig. 15.—Polype. A, actual size; B, magnified.

This is, then, the basis of a classification of what has been called the *Animal Kingdom.* There are, as we have seen, four great groups: 1. Vertebrates; 2. Annulates; 3. Mollusks; 4. Radiates. The best thing we can now do is to study these different groups, each in its turn, considering briefly the principal animals comprised therein.

SUMMARY.—DIVISIONS OF THE ANIMAL KINGDOM.

1. **Generalities** (p. 7).—An *animal* grows, moves about, feels, lives, and dies.

2. A *plant* grows, lives, and dies, but does not move out of its place, and shows no sign of feeling.

3. A *mineral* remains unchanged unless displaced, broken, or altered by some outward cause.

What is the resemblance between a sea-star and a polype? What name is given to these animals? Name the four great groups of the animal kingdom.

4. The animal kingdom comprises four great groups: **Vertebrates, Annulates, Mollusks, Radiates.**

5. **Vertebrates** (p. 10).—By this name are designated all animals that have *bones*, or what is called a *skeleton:* a horse is a *vertebrate.*

6. The name *vertebrate* is based upon the fact that among the bones of these animals those that form the spinal column are called *vertebræ.*

7. The vertebrates are the *only* animals that have RED BLOOD.

8. **Annulates** (p. 11).—The *annulates* (insects, spiders, millepeds, crustaceans, worms) are animals that have neither *bones* nor *red blood,* and whose bodies are formed by a series of RINGS juxtaposed, and that play on one another. A *wood-louse* is an *annulate.*

9. **Mollusks** (p. 13).—The *mollusks* have neither *bones, red blood,* nor *rings.* Their body is SOFT and PULPY, sometimes hidden in a shell. A *snail* is a *mollusk.*

10. **Radiates.**—Certain animals are possessed of a mouth which, unlike our own, is centrally placed. When the body is produced at the sides of this into a series of rays, such animals are often called *Radiates.* The star-fish or sea-star is a Radiate, as is also the sea-anemone.

I.—VERTEBRATES.

The VERTEBRATES, as we have already said, *are animals that have* BONES *and* RED BLOOD. They are divided into several great classes: *Mammalia, Birds, Reptiles, Amphibians,* and *Fishes.*

7. **Mammalia.**—There are, in the first place, *Quadrupeds,* which are four-footed animals, covered with hair or fur. As they nourish their young with milk, the name MAMMALIA

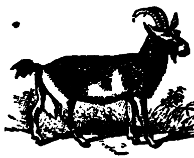

FIG. 16.—Vertebrates.—1. Mammalia (milk-givers). 4 feet (Quadrupeds), covered with hair or fur.

FIG. 17.—Vertebrates.—2. Birds. A beak, wings, feathers, 2 feet.

(Fig. 16) has been given to them, *mamma* being the Latin name of the udder, or *organ that gives milk.*

8. **Birds.**—Tell me what characterizes BIRDS (Fig. 17).

What are the general characteristics of the Vertebrates? Into how many categories are they divided, and what are they? Which group ranks first among the Vertebrates? Why is the name Mammalia given to it? What characterizes the Bird group?

What do they all possess?—"You told us that a little while ago. Birds have a beak, wings, feathers, and only two feet."—Quite right.

9. Warm-Blooded and Cold-Blooded Animals.—Can you mention what are the characters common to all REPTILES? I see this question perplexes you. And no wonder, for the *lizard* has four feet, the *serpent* has none whatever, and the *tortoise* lives shut up as it were in a box forming a sort of house. All these animals differ widely in appearance from one another, and yet they all come under the name of REPTILES. We must find out the reason why they are all put together in the same group. Come, try; I shall help you.

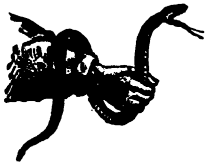

FIG. 18.—Vertebrates.—3. Reptiles. Cold-blooded animals, mostly living on the earth (aerial). Skin covered with false scales.

When you put your hand on a dog or on a horse, do you feel it to be cold or warm?—"*Warm.*"—Yes; and when you lay hold of a bird, a hen, for instance, do you feel it to be warm or cold?—"*Very warm.*"—Quite so. Now if you take a lizard in your hand, or a serpent.—"Oh! a serpent! I should never dare; it would bite me, and people die of a serpent's bite."—Don't be afraid; I would never advise you to touch a *viper* or a *rattlesnake*, but here is a pretty little *garter-snake* (Fig. 18), quite harmless. Put your hand bravely upon it: you run no risk. What do you feel?—"IT IS QUITE COLD."—And this frog?—"COLD also."—And this goldfish that I have just taken for a moment out of its globe?—"COLD, *like the serpent and the frog.*"

Here is, then, a new and very great difference that exists among animals. There are animals whose *blood is warm:* Mammalia and Birds. Others have *cold blood*, those are the Reptiles; and along with them Amphibians, which will come under our notice in a little while, Fishes, and also all animals without bone or vertebræ (Annulates, Mollusks, Radiates), the *Invertebrates*, as they are often called.

Name some animals that belong to the Reptile group. Is a garter-snake warm or cold to the touch? What groups form the class of warm-blooded animals? What groups form the class of cold-blooded animals?

10. Reptiles, Amphibians, Fishes.—*Reptiles, then, have cold blood;* this is sufficient to distinguish them from mammalia and birds. It remains to be seen what distinguishes them from FISHES (Fig. 19). What difference do you see between them?—"*Fishes live in water,* and *reptiles live on the earth.*"—Very well; or, to use more scientific terms, we say reptiles are *aerial* animals, that means animals living in air; while fishes are *aquatic* animals (from the Latin *aqua*, water).

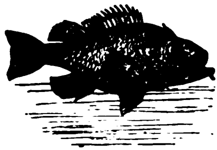

FIG. 19.—Vertebrates.—4. Fishes. Cold-blooded animals living in water (aquatic). Real scales.

Our reasoning does not seem to satisfy some of you. What have you to object to it?—"Please, where will you class the *frog* (Fig. 20)? It lives half in the air, half in the water. It is half fish half reptile."—Quite so, and your observation is sharp enough; but you make a mistake. The frog does not live half in water, it lives *in air only.* True, it jumps into the water on the least alarm, and there hides; *but were it not to come to the surface, and to put at least the point of its nose above the water so as to be able to breathe air, it would be drowned.* Some men are able to remain with their heads under water for two minutes without being asphyxiated, that is to say, suffocated; as for the frog, it can remain much longer, but not above an hour, except during the cold winter season, when the frogs become torpid, and seem quite dead. So you see the frog is an *aerial* animal, like the lizard and the serpent. The frog, however, has not been thus all

FIG. 20.—Vertebrates.—5. Amphibians. Cold-blooded animals, *aquatic* when they are young, *aerial* when developed.

What difference is there between reptiles, cold-blooded animals, and fishes that also have cold blood? Why cannot the frog be ranked among fishes?

its life. When young it was a *tadpole*, as you all know; it *then lived continually in the water*, and was an *aquatic* animal. So here is an animal which when quite young was *aquatic*, and which has become *aerial* after having undergone what is called its metamorphosis or transformation. For it and its allies, the toads, salamanders, newts, a group has been formed, called the AMPHIBIANS, which signifies *double life.*

Still another difference exists between Amphibians and Reptiles. Examine the skin of the frog, *it is moist and* nearly *smooth;* now look at that of the snake: is it smooth also?—"No, it is quite *covered over with scales.*"—Like that of a fish?—"Yes."—Look again: you have made a mistake. See, the scales of the goldfish are quite distinct and separate, so that were it handled too roughly, one or more might be wrenched out, just as a hair might be pulled from your head or a feather from a bird. This is impossible with the scales of the snake; what you take for scales are merely folds *of the skin:* they are called *false scales.*

Let us now review briefly. REPTILES are *aerial* animals; their skin is covered with false scales. AMPHIBIANS are *aquatic* animals in their youth, and *aerial* when fully developed; their skin is bare. FISHES are *aquatic* animals; their skin is covered with real scales, distinct the one from the other.

SUMMARY.—VERTEBRATES.

1. Division of Vertebrates (p. 15).—**Vertebrates** are divided into several important categories,—namely, *Mammalia, Birds, Reptiles, Amphibians,* and *Fishes.*

2. Warm-Blooded Animals (p. 16).—The MAMMALIA are hair-clad, and give milk to their young.

3. BIRDS have a bill or beak, wings, feathers, and two feet.

4. Mammalia and Birds have *warm blood.*

5. Cold-Blooded Animals (p. 17).—REPTILES have *cold blood,* their skin is covered with false scales.

6. AMPHIBIANS have cold blood, their skin is bare. When young they live in water and are *aquatic.* When full grown they breathe air, and are obliged to come to the surface for this reason: they are then aerial animals.

What was its mode of existence when it was a tadpole? What deduction do you draw from this fact? What group has been formed for animals of the same kind as the frog? What are the characteristics of reptiles? What are those of the amphibians? What are those of fish?

7. From this double life they take their name of ***Amphibians***, a word signifying *double life*.

8. Fishes have cold blood, are *aquatic*. Their skin is covered with *real scales*, distinct from one another.

[Easy subjects for composition may be found at page 83.]

1. Mammalia.

11. Mankind.—We will begin the study of Mammalia with *mankind;* for man belongs to that class.

I willingly allow that man would have well merited a particular division, all for himself, so great is his superiority over all the other members of the group. But let us for a moment forget our intellectual faculties, and consider only our body: in this case we cannot but confess that we have no little resemblance to monkeys.

We walk upright, however, and stand erect on our two legs, and that monkeys cannot do; we have strong and yet delicate hands, with which, on account of the existence and position of the thumb, we can grasp firmly or feel nicely. Our body is almost bare, except the head and part of the face.

All the members of the human family who live dispersed over the surface of the globe are not exactly similar to the men of this country. Even here among our acquaintances there are fair people and dark people, different from each other in feature as well as in complexion. A big fair-haired native of Denmark and a little dark Italian resemble each other still less. But all the populations of *Europe* have a WHITISH skin, as we have (Fig. 21), regular features, a straight nose, well-poised jaws, and smooth but silky and sometimes wavy hair. *Chinese* (Fig. 22) have a YELLOWISH skin; their hair is smooth, black, and rough; their eyes are obliquely set, their teeth prominent. *Negroes* (Fig. 23) have a BLACK skin, frizzled woolly hair, very prominent jaws, and a broad, flattened-out nose. The North American Indians (Fig. 24) somewhat resemble the yellow race, only the men are taller and stronger, and their skin has a REDDISH tint. There are also many other races of less numerical importance or

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What are the principal races among men?

less easily defined. We will for the time being take notice only of the *white* race of Europe, the *yellow* race of Asia,

FIG. 21.—White race (Europe).

FIG. 22.—Yellow race (Asia).

the *black* race of Africa, and the *red* race of America. Only you must know that white men, being more intelligent, more

FIG. 23.—Negro race (Africa).

FIG. 24.—Red race (America).

industrious, and more courageous than the others, have spread over the whole world, so that the inferior races disappear as they are crowded out by the whites.

Moreover, the inferiority of some races of the human family is very plain. For instance, the people of the aboriginal race of Australia are of stunted stature, with blackish skin, straight black hair, and very small heads. They live in groups, and neither cultivate the ground nor possess domestic animals except a sort of dog. Their intelligence is very limited. In other parts of the world there exist some tribes that do not even know how to make fire.

12. Monkeys.—In the highest rank among *monkeys* or apes we must place three great species much more intelli-

Fig. 25.—Orang-outang (Borneo).

Fig. 26.—Gorilla (Africa).

Fig. 27.—Chimpanzee (Africa).

gent than the others, and having closer resemblances to the human family.

The most anciently known of these large monkeys is the *orang-outang* (Fig. 25), which lives in the forests of Borneo, and whose stature sometimes reaches the height of more than four feet. On the Gaboon coast and in Guinea the enormous *gorilla* (Fig. 26) is to be found. This powerful animal has been known to attain the height of six feet. The *chimpanzee* (Fig. 27) also is an inhabitant of these countries; its height rarely goes beyond four feet.

These animals have no tail; they walk generally with the help of both feet and hands, putting only, however, the knuckles of these last to the ground; sometimes they even stand almost erect like a man. But, like all other monkeys, their great toe is like a real thumb, separated from the other

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Name the three highest genera of monkeys.

toes as our thumb is from our fingers; this permits them to climb with the greatest ease; they are able to seize the branches of trees with their feet as well as with their hands. This is the reason why you will find that monkeys are often designated by the name of *Quadrumana* (four-handed), whilst the name of *Bimana* (two-handed) is applied to man.

These great monkeys live in small families, are extremely intelligent (of course I mean for animals), are easily tamed when caught young, and can be sometimes trained to make themselves useful in household service on account of their size and their almost erect gait.

Fig. 28.—An African monkey.

The other species of monkeys are extremely numerous. They live in the warm climates of both hemispheres, almost always in countless troops, gay and noisy, always climbing, gambolling, and teasing one another in the forests, where they feed mainly upon fruit (Fig. 28).

13. Bats.—We shall now pass on to the *Bats*. I am sure that at first thought it astonishes you that I should class the Bats among *Mammalia*. Have they not wings? I have no doubt that the fact of their flying would rather induce you to consider them as *birds*.

Fig. 29.—Bat (Mammalia).—The bat has neither beak nor feathers, but has hair, ears, and teeth. Its wings are composed of the skin of the back and breast stretched out, and sustained by the prolongation of the finger-bones.—Nocturnal animals, useful to agriculture.

In order to give you proofs against such an error, I caught one last night, by means of a light, and put it in the school-room, leaving the window open. Here it is, quite unharmed, under this glass shade. Let us set to work and examine it (Fig. 29).

In the first place, we see that its *body is covered* not with feathers, but with *hair;* moreover, its head is adorned with a pair of *long ears*, and certainly you never saw

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What name is often given to monkeys? Why cannot bats be ranked among birds?

a bird have ears. To enable us to examine it more closely I will take it out of its prison; only, for that purpose, I shall prudently, but without hurting it, make use of a pair of pincers. Why so? Because it has very *sharp teeth*, and would be very ready to use them on my hands. You never heard of a bird's having teeth, did you? Thus the bat has neither a beak nor feathers, while it is provided with teeth, long ears, and fur: it cannot, then, be a bird.

And its wings? Ah! they also demand close examination. See, I have spread one out completely. How different it is from a bird's wing! It has no feathers whatever; it is composed of a *thin membrane* or film stretched out upon a bony frame and unfolding like a fan. The bones are in reality those of the fingers considerably lengthened out. The membrane is double, and is formed by a prolongation of the *skin of the back and that of the breast*, which has become in that particular place very thin. This membrane extends from the arm to the tail, embracing this and the leg. It is certainly a very odd kind of wing.

Now, in order to see how our bat can use these strange wings, we will set it free. See, it flies away clumsily and heavily, and seems not to know where to direct its flight. Can you tell me why? Of course you can. It is because the sun is bright, and the poor bat, which shuns light and never comes out of its corner until twilight, being what is called a *nocturnal* or night animal, is dazzled. Ah! it has found the open window, and will now be able to go and hide itself in some dark hole or cellar. There, with its wings folded, it will suspend itself by its hind claws, and will sleep head downward all day long. In the evening it will wake up again, and go forth to hunt insects, among which it makes great havoc. So you see *the poor little creature is a friend to gardeners and farmers, and deserves to be protected.* Some foreign bats are fruit-eaters.

During winter, bats remain in their holes, where they sleep

What is the difference between a bat's wing and a bird's wing? What name is given to animals that, like the bat, avoid the light of day? What is the principal food of bats? What must we conclude from this? Why are bats said in winter to be in a dormant state?

all through the cold season, and need neither food nor drink. They are then in what is called a *dormant* or *hibernating state.*

14. Insectivorous Animals.—Other mammalia, wingless this time, *live upon insects:* hence the name *Insectivora*, or insect-eaters, sometimes given to them. They are all of small dimensions: you can easily understand that such food would scarcely be sufficient to keep alive large animals.

One of the most noted of the insect-eaters is the *hedgehog* (Fig. 30), whose hair forms great spines, which serve it as defensive weapons when it rolls itself up in a ball; it also is an animal that sleeps during winter,—a hibernating animal.

Fig. 30.—Hedgehog. Instead of hair it has spines. It sleeps through the winter.

Fig. 31.—Mole. It eats white worms or larvæ (and therefore should not be destroyed).

The *mole* (Fig. 31), which with its strong broad feet hollows out underground galleries, is another example: it has extremely small eyes, which, like the openings of its ears, are hidden in its soft silky fur. *It is a great mistake to destroy the mole*, as people often do: it never eats the roots of plants, but swallows countless numbers of destructive *larvæ* and *worms* that live deep down in the earth.

The *shrew mole*, another insect-eater, is very like the common mole, except that its nose is longer and sharper, and its well-whetted teeth are perfectly adapted to its mode of life, enabling the little creature to break open the thick and crusty carapace of insects.

15. Carnivorous Animals.—We will now begin to study animals that live upon flesh, that devour mammals and birds

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What is meant by the word insectivorous? What is in general the size of insectivorous animals? Name some of these animals. Why should the mole not be destroyed? What name is given to flesh-eating animals?

alive. Those are the *Ferine*, or *carnivorous animals* (from the Latin *caro*, *carnis*, flesh, and *vorare*, to devour).

The most perfect and complete type of the race, and the best fitted for the chase, is the CAT. Let us, then, examine our good pussy, if she will kindly allow us to do so. Look at her paw, in the first place: see how it is armed with sharp cutting claws; she well knows their value, and takes good care of them, for when not required they are withdrawn into the paw (Fig. 32), so that their points do not even touch the ground; this keeps them always in good working order. The sharp point of the claw never comes out of its sheath except when the animal stretches out its toes to climb or to strike its prey (Fig. 33). Look at its mouth (Fig. 34); see on each side these long, strong, and pointed teeth that lay hold of the prey, and behind them those others, sharp and cutting, that play upon one another like the blades of a pair of scissors, tearing up the flesh. What weapons these are! If a common cat can use them so as to do great harm, just think how a lion or a tiger might employ them. *For the tiger and the lion are merely enormous cats*, able to treat a man as a cat treats a mouse.

The most formidable and fierce of the tribe, the *tiger* (Fig. 35), with its beautifully-striped skin, is a native of

FIG. 32.—Cat's paw in repose. The sharp claws do not touch the ground.

FIG. 33.—Cat's paw just going to strike its prey. The claws are stretched out.

FIG. 34.—Cat's mouth. Four long pointed teeth in front; sharp back teeth.

Asia. It is exceedingly bold and daring, and attacks man

To what well-known class of animals do the lion and the tiger belong?

with such ferocity that in 1875, in British India alone, 917 men fell a prey to tigers.

The *lion* (Fig. 36), an inhabitant of Africa and of certain

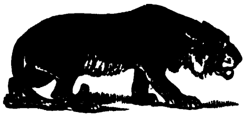

FIG. 35.—Tiger (Asia).

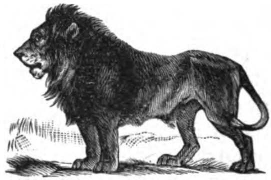

FIG. 36.—Lion (Africa).

regions of Asia, is less aggressive; but it preys heavily upon wild and domestic animals. It has been calculated that each

FIG. 37.—Panther (Africa and Asia).

FIG. 38.—Jaguar (Central and South America).

lion in Algeria costs the colony about four thousand dollars yearly.

The beautifully-spotted *leopard* or *panther* (Fig. 37) very rarely attacks man. Several species of its kind are to be met with in Africa and in Asia.

In Central and South America lives the *jaguar* (Fig. 38), almost as big as the tiger, but not nearly so dangerous to mankind: its skin is covered with spots. The *puma* (Fig. 39), whose grayish-brown skin is neither spotted nor striped, bears also the name of the *American lion*, and it is often called *panther*, for its habits much resemble those of the latter animal.

The only animals of the cat kind in Europe are the *wild-cat* of the forests, supposed by some to be the ancestor of our common domestic cat, and the *lynx* (Fig. 40), which is still

met with on some high mountains. A large species of lynx, commonly called *wild-cat*, is found in the Northern United States and Canada.

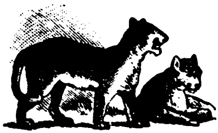

FIG. 39.—Puma (North and South America).

FIG. 40.—Lynx (North U. S.)

Next to the *Cats* come the *Dogs*. Fig. 41 represents the *dingo*, or wild dog of Australia. The teeth of the dog family somewhat resemble those of cats; but their claws are fixed, and cannot be drawn in like those of pussy. We have *wolves*, which, though not very dangerous in America and Western Europe, are much to be feared in Asia and in the east of Europe, where they live in great bands; in Russia they devour, on an average, upward of ten millions of dollars' worth of cattle yearly. We have also the *fox* (Fig. 42), a sly and clever hunter, that hollows out a home to dwell in.

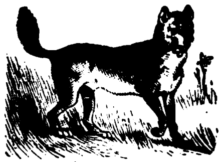

FIG. 41.—Dingo.

FIG. 42.—Fox.

In Algeria and in other parts of Africa, also on all the Asiatic shores of the Mediterranean Sea, and even in Greece, lives a sort of little wolf, the *jackal* (Fig. 43), that makes great havoc among fowls and game.

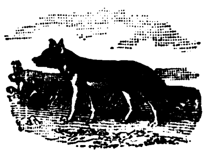

FIG. 43.—Jackal (Africa). Destructive to game and poultry.

The *hyenas* (Fig. 44) are African and Asiatic animals; they are big and strong, but prefer dead bodies to live flesh. They never attack man.

Bears are to be found all over the world, except in Africa

and Australia. The common bear of our country is black. In Europe there is the *brown bear* (Fig. 45); it lives in the

Fig. 44.—Hyena (Africa). Never attacks man.

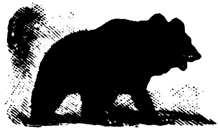

Fig. 45.—Brown Bear of the Pyrenees. Prefers fruits and honey to flocks and herds.

Alps, in the Pyrenees, etc.; these bears are not much to be dreaded by man, being of a peaceful disposition, for they prefer, like many of their relatives, fruit and honey to the flesh of flocks and herds. The *white bear* (Fig. 46), which is to be met with in Greenland and in all icy regions of the north, and the *grizzly bear* (Fig. 47), the most savage animal of West-

Fig. 46.—White Bear (icy regions). Height, 47 inches.

Fig. 47.—Grizzly Bear (North America).

ern North America, are not of so accommodating a nature: they do not hesitate to attack man, and it is often extremely difficult to get out of their reach. The *raccoon* is a member of the bear family, but, as you know, it is much smaller than the bear.

The *badger*, a native of American and European forests (Fig. 48), has some points of resemblance to the bear: it is exceedingly fond of fruit, but by no means disdains to pay a visit to the poultry-yard.

Great enemies of fowls and small game are the *ferret*

(Fig. 49), the *marten* (Fig. 50), the *weasel*, the *ermine*

FIG. 48.—Badger.
Eats grapes and poultry.

FIG. 49.—Ferret. FIG. 50.—Marten.
Live on poultry and small game.

(Fig. 51), and the *polecat* (Fig. 52), all of which are long slender creatures, common in American and European forests. The *sable* is a marten, and the *skunk*, which, like the

FIG. 51.—Ermine. FIG. 52.—Polecat.
Eat poultry and small game.

polecat, has the power of producing a most unpleasant odor, is a kind of weasel. The *wolverene* of Canada, Siberia, and Northern Europe is a larger animal, and exceedingly voracious. It is a great enemy of the hunter, for it steals their game from the traps.

These animals are hunted by man, not only to punish their depredations, but also because their skin affords warm and beautiful *fur*. The colder the country in which an animal lives, the finer and thicker is its fur. In Canada and Siberia millions of skins are sold yearly, and it is the martens, ermines, and sables that furnish the greater part of this costly merchandise.

FIG. 53.—Otter. Destroys fish.

The *otter* (Fig. 53), another long-bodied animal, pursues and destroys the fishes in our ponds and rivers.

16. Edentata.—The *Edentata*, or so-called toothless animals, are strange creatures, unknown in Northern countries. They have few if any teeth, and feed on tiny insects. The most remarkable member of this family is the *great ant-eater* (Fig. 54), an inhabitant of South America. Its length sometimes attains four feet nine inches, not including the tail, which appendage measures about two feet four inches. It has no teeth, but is provided with a pointed tongue about fifteen inches long, covered with slimy and sticky saliva; this it thrusts into ant-hills or across their wonted paths. The unsuspecting ants that venture thereupon are doomed to death, being unable to free themselves, and when a sufficient number is thus caught the ant-eater draws back its tongue, covered with the living burden, into its mouth.

FIG. 54.—Great Ant-Eater (South America). Lives on ants.

17. Rodentia.—We have now passed in review the more interesting and important of the flesh-eating animals. Let us glance at some of the plant-eaters, or *Herbivorous animals*.

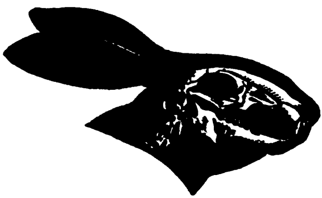

FIG. 55.—Rabbit's head (herbivorous gnawing animal).

The first in order are the *Rodentia*, or gnawing animals. Look at this picture: it represents a *rabbit's* head (Fig. 55). In each jaw you will observe two long teeth, which rub upon each other so as to gnaw vigorously whatever happens to come between them; the under jaw works backward and forward so as to produce the necessary rubbing and gnawing movement. This rubbing wears the teeth, but, since they grow as fast as they wear out, they always remain of the same length.

The principal common members of the rodent family are

What name is given to plant-eating animals? To what do the squirrel, rabbit, and mouse owe their name of gnawing animals?

the following: the *squirrel* (Fig. 56), nimble as a monkey, so gay, so pretty, and so lively, in summer at least,—it sleeps in its nest all through the winter; the European *dormouse* (Fig. 57), smaller than the squirrel, but quite as pretty,

FIG. 56.—Squirrel. Rodent.

FIG. 57.—Dormouse. Rodent.

and more dormant still, for even in summer it sleeps soundly all day long, and seeks its food at night; the *rat*, the *mouse*, the *wood-mouse*, and the *field-mouse* (Fig. 58), all of which

FIG. 58.—Field-Mouse. Rodent.

FIG. 59.—Hare. Rodent.

have earned by their stealing such a bad reputation; the *hare* (Fig. 59) and the *rabbit*, well known to everybody.

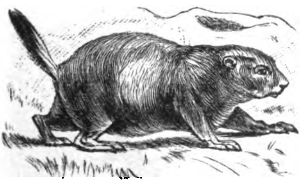

FIG. 60.—Prairie-dog. Rodent.

FIG. 61.—Woodchuck. Rodent.

Very interesting little animals are the *prairie-dogs* (Fig. 60), which inhabit the prairies west of the Mississippi: they live in burrows that are called prairie-dog villages, many

families of them living together. They are exceedingly agile, and travel under ground with such rapidity that it is very difficult to capture them.

The *woodchuck* or *ground-hog* (Fig. 61) of the Northern United States and Canada is a kind of marmot.

We may also mention among rodents the *beaver* (Fig. 62). Some stray members of this family are to be found along the

FIG. 62.—Beaver (North America). Rodent.

FIG. 63.—Porcupine (Italy and Africa). Rodent.

banks of the Rhone, but their principal quarters are in North America. Here they formerly lived in large colonies, but they are now found only in the wildest regions: they construct dams upon the rivers and build themselves houses, cutting the necessary wood with their powerful teeth. Their broad scaly tails aid them in swimming, and are not used in plastering the mud on their houses as was formerly supposed.

In Italy and in Africa are found *porcupines* (Fig. 63); they sometimes weigh over 30 pounds, and they are armed all over with strong, sharp quills, sometimes a foot long. A kind of porcupine is found also in the Northern United States and in Canada, where it is wrongly called *hedgehog*.

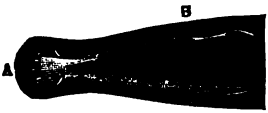

FIG. 64.—Lower jaw of a horse. A, front teeth; B, flat molar teeth (herbivorous).

FIG. 65.—The horse has only one *toe*, which terminates in a nail forming the hoof.

18. Horses.—*Horses* are real herbivorous, or grazing animals, as you all know; the nature of their food might indeed

be guessed by the mere examination of their back teeth (Fig. 64). Instead of being unimportant, like those of insect-eaters, or armed with sharp points or blades, like those of flesh-eaters, theirs are *flattened out*, and can act only as grind-stones to bruise the grains and grasses on which they feed.

A distinctive character common to all the horse kind is that each foot has but *one toe*, ending in a sort of nail, which completely envelops the extremity of the toe, forming what is called the *hoof* (Fig. 65).

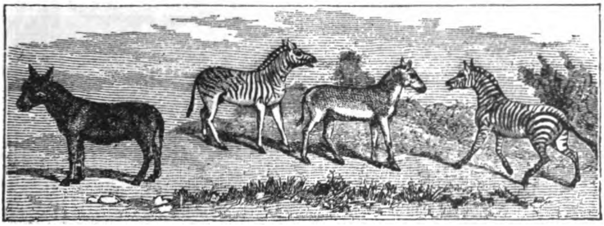

FIG. 66.—1. Ass; 2. Quagga; 3. Wild Ass; 4. Zebra.

The principal animals of the horse kind are the *horse*, properly so called, the *ass* (Fig. 66, 1), the *quagga* (Fig. 66, 2), the *wild ass* (Fig. 66, 3), and the *zebra* (Fig. 66, 4).

19. Ruminantia.—You have doubtless all seen a cow or a sheep *chewing the cud*, or *ruminating*, to use the scientific expression; that is to say, chewing, although they have apparently nothing to eat. I will explain to you how this happens. These animals eat very fast, and masticate but imperfectly when doing so. When they have laid in enough, and are at rest, they have the power of *bringing the food back into their mouth;* it is then chewed at leisure, so as to facilitate the digestion when finally swallowed.

Almost all the ruminating animals are of considerable size; some are even enormous. Their molar, or back teeth are flat, like those of the horse; their stomach is composed of

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What peculiarity do the molar teeth of horses present? What distinctive character is common to horses? Name the principal animals of the horse kind. What is meant by the word *ruminating?* How does rumination take place? What peculiarities do the molar teeth of ruminants possess? And their stomachs?

several pouches, and it is this peculiar character that allows *rumination*, for they first pass the unchewed food into one of these pouches, from which they can return it to the mouth. Their feet have two toes, each of which is protected by a hoof (Fig. 67). The first in order of this description that I shall

FIG. 67.—A foot with two toes. Ruminants (cows, sheep, camels, deer, giraffes, etc.).

FIG. 68.—Camel with one hump, or African dromedary. Very useful. Ruminant.

mention is the *camel*, two domesticated species of which are well known,—the *camel with one hump*, or African *dromedary* (Fig. 68), and the *camel with two humps*, a native of Asia

FIG. 69.—Camel with two humps (Asia). Is of great use. Ruminant.

FIG. 70.—Llama (South America). Small camel-like animal without a hump. Ruminant.

(Fig. 69). Both of these are equally useful on account of their strength, their docility, and their fitness for desert life.

In South America there exist animals that bear some re-

How many toes have these animals? Name some different species of ruminating animals

semblance to the camel, except that they are smaller, and have no hump. Of these camel-like animals, the *llama* (Fig. 70) and long-haired *alpaca* have been domesticated by the Indians.

The *giraffe* (Fig. 71) sometimes stands 18 feet high: it is found only in Africa, and but one species is as yet known.

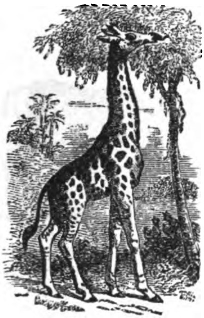

FIG. 71.—Giraffe (Africa). Height, 18 feet.

FIG. 72.—Red Deer. Ruminant.

FIG. 73.—Roe-Deer (Europe). Ruminant.

FIG. 74.—Fallow-Deer (Europe). Ruminant.

The *Deer family*, on the contrary, comprises a great number of species, which are to be found in America, Europe, and Asia.

Their principal characteristic is that the head of the male is provided with *solid horns*, which are outgrowths of the bones of the skull, *that fall off and are renewed every year.*

Name some other species of ruminating animals.

We have the *red deer* (Fig. 72), the *roe-deer* (Fig. 73) and the *fallow-deer* (Fig. 74) of Europe, the *elk* (Fig. 75), of the northern regions of America and Europe, about the size of the horse, and the *reindeer* (Fig. 76), so useful as a sub-

FIG. 75.—Elk (North America). As large as a horse. Ruminant.

FIG. 76.—Reindeer (Europe). Ruminant. A most useful animal in the icy regions.

stitute for the horse in the icy wastes of Northern Europe. The female of the reindeer has horns like the male.

FIG. 77.—Bison, or Buffalo (North America). As large as an ox. Ruminant.

See, here is a cow's horn: it is a sort of *hollow sheath.* On the beast's head, this sheath fits over a sort of bony protuberance of the forehead, which fills it exactly. The *protuberance and its sheath are never shed.* All the ruminants that bear horns of similar description form a class apart, and are called *Hollow-horned Ruminantia.*

Oxen are the largest animals of this kind, and also the most interesting. In America, Europe, Africa, and Asia several species have been domesticated, but there is still found, not

What is remarkable about the horns of deer? Name some species of the deer family. What peculiarity do cows' horns present?

only in Africa and Asia but also in Europe, a big-headed, humpbacked wild ox. This animal lives in the forests of Poland, and is not unlike the *bison*, or *American buffalo* (Fig. 77), which, until a short time ago, inhabited in countless herds the prairies of North America. Unfortunately, the wanton destruction of the buffalo has resulted in leaving only a few herds in the whole Western territory. The largest of these is in the Yellowstone National Park.

Sheep and *goats* are also numbered among domestic animals. But there exists in the Alpine mountains and in

Fig. 78.—Bouquetin, or Wild Goat of the Alps. Ruminant.

Fig. 79.—Wild Sheep of Asia. Ruminant.

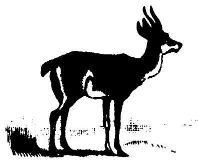

Fig. 80.—Gazelle. Ruminant.

the Pyrenees a sort of wild goat (Fig. 78), and in Siberia and Central Asia there is found a wild sheep (Fig. 79).

Lastly, the general name of *Antelopes* is applied to a very numerous species of other hollow-horned ruminants, of varied form and size, that live in herds in Africa. The African *gazelle* (Fig. 80) has a world-wide celebrity for its beauty. One species of these agile and graceful creatures, natives of South Africa, when migrating from one place to another, travel in herds of about 20,000 head, carrying along in their ranks whatever other animals they happen to meet. In Europe only one species is found, the *chamois* (Fig. 81) of the Alps and Pyrenees. Immense herds of a large kind of antelope roam over the Western territories of the United States.

Fig. 81.—Chamois of the Alps and Pyrenees. Ruminant.

20. Elephants.—The *elephant* (Fig. 82) is the largest of all land-animals: it sometimes attains the weight of 14,000

pounds, and is more than 9 feet high. Everything is remarkable in this strange animal: the prolongation of the snout, which forms the long flexible trunk it uses so cleverly; the two enormous teeth, called *tusks*, that adorn its upper jaw, and which furnish useful and beautiful ivory; its great in-

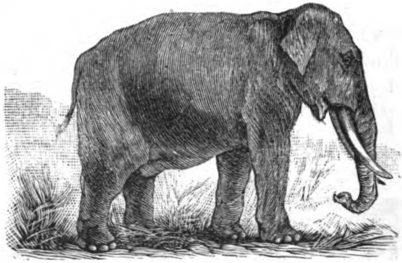

FIG. 82.—Elephant of India. Weight, 14,000 pounds. Height, 15 feet.

telligence and its tamability; the great services it can render by carrying burdens in the chase or in war, etc.

Two species of this powerful animal are known: one is a native of India and Ceylon, and is at the present day the only domesticated one. The other, which has large ear-flaps and a prominent forehead, lives in Africa. The negroes make no use of it except to hunt it for its ivory; but in ancient times it was much employed by the Greeks and Romans, and there is no reason why it should not be made use of in our day.

FIG. 83.—Wild Boar. Pachydermata.

21. Pigs.—One of the important mammals that we have not yet studied is the *pig*. This creature is only a domesticated form of the *wild boar*, which is very numerous in the forests of Europe (Fig. 83).

Passing over the several species of wild boars that are found in Asia, Africa, and America, the most interesting of those remaining is the *hippopotamus*.

Which is the largest of all land-animals?

The *hippopotamus* (Fig. 85) is very massive and heavy, so much so that on land its movements are by no means graceful. In the water, however, where it lives almost constantly, it is quite agile. It has an enormous mouth set with great massive teeth, which yield a precious variety of ivory. The

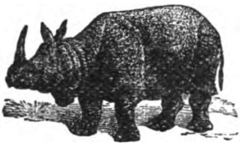

Fig. 84.—Rhinoceros (Asia and Africa).

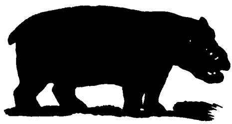

Fig. 85.—Hippopotamus (rivers of Africa).

hippopotamus is to be found in almost all the large rivers of Africa. These pig-like animals, and the *rhinoceros* (Fig. 84), have a thick leathery skin, for which reason they were once grouped together and called *Pachydermata*.

This, however, is an error, for the rhinoceros, strange as it may appear to you, is now known to belong to the same class of animals as the horse. The horn of the rhinoceros is not joined to the bone of the head, but to the skin, and can easily be detached by cutting around its base. The rhinoceros is a savage animal when irritated, and is of very uncertain disposition.

22. Marsupialia.—In the continent of Australia there

Fig. 86.—Kangaroo (Australia). Has a pouch in which its young are protected. Marsupialia.

Fig. 87.—Ornithorhynchus (Australia). A duck's beak, web-footed.

Fig. 88.—Opossum (America). Marsupialia.

exist, except the dog and some of the bat tribe, no mam-

What name is given to thick-skinned animals? Which are the most interesting of the so-called Pachydermata?

malia having much resemblance to those of the other parts of the world. *The mammalia found in Australia have quite peculiar characteristics.*

As in most cases the young of these animals, when newly born, take refuge in a sort of pouch (in Latin, *marsupium*) situated under the mother's abdomen, the name *Marsupialia* has been given to the group.

Among Marsupialia there are *flesh-eaters*, *insect-eaters*, and *grazing animals.*

The best-known of these last is the *kangaroo* (Fig. 86), a strange creature, that with the help of its tail and enormous hind legs is able to travel by prodigious bounds when pursued or otherwise hurried. The largest species of this animal attains the height of 6 feet, and even more.

Another strange Australian mammal is the *ornithorhynchus* (Fig. 87), whose jaws are prolonged into a flattened bill like that of a duck; it is also web-footed, but it is not a marsupial.

Only a few of the Marsupialia group are found out of Australia: one of them is the *opossum* (Fig. 88), a native of the United States. This little creature lives on flesh. By the aid of its long, hairless tail, it can suspend itself from the branches of trees. It is a cunning animal, and when captured it very perfectly feigns death (or, some say, faints with terror).

23. Seals.—All the animals that have until now occupied our attention live on land. True, the *otter* seeks its prey under water; there also the *hippopotamus* passes a great part of its life: but, although fond of bathing and river life, they come ashore, and walk and run on the dry land.

This is not the case with *seals* (Fig. 89): their feet, flattened out and shaped like fins, enable them only to drag their bodies heavily along the ground. Almost the whole of their life is spent in the sea, and they swim and dive with marvellous agility. They live altogether on fish.

Some few seals are to be met with on our coasts, but in small groups only: their real home is on the icy shores of the

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What peculiarity do the mammals of Australia possess? Why is the name *Marsupialia* given to a group of Australian mammals? Among the mammalia already studied, name two that willingly stay in water although they come on dry land. Name some mammalia that pass nearly all their lives in water.

northern and southern seas of both hemispheres, where they are wantonly and foolishly slaughtered. In 1870 the Scotch fishermen captured and killed 90,000 of these animals. Enormous numbers of seals are found on the coasts of Alaska Territory. The fat or oil of seals is used for industrial purposes, and the skin of some kinds gives a beautiful fur.

In the northern seas, there live, in herds also, animals akin to the seal; these are *walruses*, or *sea-horses* (Fig. 90),

Fig. 89.—Seals. Live in bands, on the banks of rivers and in cold regions.

Fig. 90.—Walrus, or Sea-Horse (northern seas). Is a very dangerous animal. Has two enormous tusks.

specially remarkable for the enormous tusks that adorn their upper jaw. They are very dangerous animals, sometimes more than 20 feet long, and when attacked in their native element they rush upon the boat, often upsetting it.

24. Cetacea.—Cetacea are mammalia that never come on

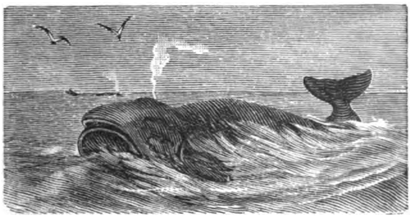

Fig. 91.—Whales. They have no scales. Fans, or whalebone, in the upper jaw. Warm-blooded. Give milk to their young (Mammalia). Come to the surface of the water to breathe (aerial). Sometimes are 107 feet long. Very narrow throat. Cetacean.

shore, for they cannot live out of water; if they happen to be cast by some tempest upon the sea-shore, they perish very

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Mention a mammal that is akin to the seal.

rapidly. They are divided into two groups (Fig. 91), *whales* and *porpoises*.

Many people have the idea that whales are fishes. Were any one to say so to you, what would you answer?—"I would answer, *that fishes have scales, while whales have none.*" —Well, and what else?—"Ah! I don't know if whales have warm or cold blood."—They have *warm blood.*—"Then whales cannot be fishes."—Certainly not; besides, *they give milk to their young*, and they are *obliged to come to the surface to breathe;* for they would die by drowning were they to remain under water more than half an hour. You see, a whale is not only an AERIAL animal, but also a MAMMAL.

But the Cetacea are strange members of the mammalian family. They have the outward form of a fish, the tail has become a fin, only it is placed horizontally, instead of being vertical like that of a fish. Their fore-limbs are fashioned like oars, or fins, whilst the hind ones are totally wanting.

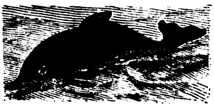

FIG. 92.—Porpoise, or Dolphin. Live on fish. Cetacean.

Among cetaceans some have teeth, and devour prodigious numbers of fishes. *Porpoises*, or *dolphins* (Fig. 92), are of this class. Many of these animals are to be seen playing and rolling in the sea around our coasts.

A large cetacean, the *cachalot*, or *sperm whale* (Fig. 93), has teeth in the under jaw. It is sometimes 75 feet long, and is very dangerous.

Whales, properly so called, have no teeth; only *the roof of their mouth* is set instead with several rows of long, flat, and flexible horny growths, called *fans*, which are used under the name of *whalebone*. These enormous animals have been known to attain the great length of 107 feet, and to weigh 500,000 pounds, which is about equivalent to that of forty elephants.

Enormous as these animals are, they feed almost exclu-

In what way does the skin of the whale prove that it is not a fish? What deduction do you draw from the temperature of its blood? How does it feed its young? In what manner does it breathe? Of what shape is the tail of Cetacea? For what do their forefeet serve them? Name two cetaceans that have teeth. What take the place of teeth in whales? On what do they live?

sively on very tiny marine creatures, that float in great shoals on the surface of the sea. Why so? I think I can hear you ask; why do the whales not eat fishes, for certainly there is no

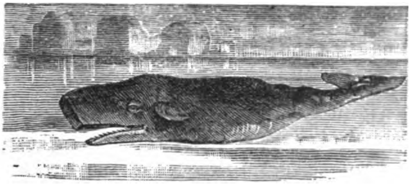

FIG. 93.—Cachalot, or sperm whale. Has teeth in the under jaw. Is sometimes 75 feet long. Is very dangerous. Cetacean.

lack of them? Well, it is because their throat is too narrow to allow them to swallow fishes: a herring would scarcely find room to pass through it.

Whales are hunted for the whalebone of their fans, and also for the oily grease that lines their skin and protects them from the cold.

SUMMARY.—MAMMALIA.

1. **Mankind** (p. 19).—MAN belongs to the Mammalian group.
2. There are four principal races among men: the *white* Europeans, the *yellow* Asiatics, the *black* Africans, and the *red Indians* of North America.
3. Some *less numerous* inferior races also exist.
4. **Monkeys** (p. 21).—First in order among MONKEYS are three great genera: the Asiatic *ourang-outang,* the African *gorilla* and *chimpanzee.*
5. The other kinds of monkeys are extremely numerous.
6. The large species as well as the small live in warm climates.
7. **Bats** (p. 22).—BATS are not birds, butm ammals. They are clad in fur, not feathers; they have teeth and erect ears; their wings are composed of a fine film or membrane, which is a prolongation of the skin of their bodies, and which is stretched out upon elongated finger-bones.
8. In the daytime bats sleep. During the night they fly abroad in search of insects, on which they feed. Therefore they are useful to farmers, and ought to be protected.
9. **Insectivorous Mammals** (p. 24).—Other INSECTIVOROUS animals that have no wings feed on insects; they are all small. Among them we may mention the *hedgehog,* whose skin is covered with prickles; the sharp-nosed *field-mouse;* the *mole,* which swallows enormous numbers

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What articles of commerce do we derive from the whale?

of white worms, and by no means eats the roots of plants as people generally imagine.

10. Carnivorous Mammals (p. 24).—The CARNIVOROUS animals (Latin, *carnis*, flesh) live upon flesh.

11. Their paws are very strong, and armed with sharp and powerful nails called claws; their mouth is set with long, strong, and sharp teeth.

12. The best type of these animals is the CAT species (p. 25). The *tiger* (the fiercest of wild beasts), the *lion*, the *panther*, the *jaguar*, all three less dangerous to mankind than the tiger, are in reality only very large and powerful Cats.

13. Next to the Cats we find DOGS (p. 27), in which species are ranged the *wolf*, dangerous in Asia and in Russia, the *fox* and the *jackal*, great ravagers of poultry-yards.

14. The HYENAS (p. 27) are fonder of dead bodies than of live flesh.

15. The BROWN BEAR (p. 28) of the Alps and Pyrenees prefers fruit and honey to the flesh of man or that of his flocks and herds. On the contrary, the *white bear* of the icy regions and the *grizzly bear* of North America are extremely savage, and attack man even when unprovoked.

16. Edentata (p. 30).—The EDENTATA, which possess few if any teeth, are unknown in European countries. The most interesting member of the group is the *great ant-eater*, whose long, worm-shaped tongue proves fatal to all ants that venture upon it, on account of the slimy substance it secretes.

17. Herbivorous Mammals (p. 30).—The HERBIVORA feed upon grasses.

18. The first in order among these are the GNAWING animals, such as *rabbits, squirrels, dormice, rats, mice, beavers, marmots*.

19. The HORSE TRIBE (p. 32), which includes the *ass*, have flat back teeth; on each foot but one finger or toe exists, which is completely enveloped by a nail. This nail forms the *hoof*.

20. Ruminantia (p. 33), so called because they *ruminate*, or *chew their cud*, which action consists in chewing food that has been previously swallowed.

21. The teeth of ruminants are flattened like those of the horse tribe; their stomach is composed of several pouches; each foot has *two toes*, terminated each by a hoof, and they are hence called cloven-footed.

22. The Ruminants include the *one-humped camel*, or African *dromedary*, and *the two-humped* Asiatic *camel*, which afford in their native countries the services horses render in ours; the *llama* of South America, domesticated by the Indians; the *giraffe* of Africa, that stands 18 feet high; the *deer, roe-deer, fallow-deer, elk*, and *reindeer*, the last-named of which is used as a beast of burden in the Polar regions, and all of which have solid horns that fall off and are renewed every year; *oxen, bisons*, formerly abundant on the prairies of North America, *sheep* and *goats, antelopes*, the *chamois* of the Alps and Pyrenees, all having hollow horns that last all their life long. The horns of the American antelope are cast every year.

23. Elephants (p. 37).—The ELEPHANTS are the largest of all terrestrial animals. They render great services in carrying heavy burdens. The Asiatic species has been domesticated, but the African elephants remain savage.

24. Pigs.—Among the *Pig* kind we have the *wild boar* and the *hippopotamus*. The *rhinoceros* was formerly classed with the Pigs, on account of the thickness of its skin, but it is now known to be related to the horse.

25. Marsupialia (p. 39).—The MARSUPIALIA, except one species, are Australian animals. Under their abdomen they have a pouch (*marsupium*) in which they carry their young. The best-known among them is the *kangaroo*. The *opossums* are natives of America.

26. Seals (p. 40).—The SEALS spend the greater part of their life in the water. They live in herds on the shores of the northern seas, where they are slaughtered in great numbers in order to obtain their oil and their skin. The *morse*, or *walrus*, with its long tusks, is classed with the seal.

27. Cetacea (p. 41).—The CETACEA, or WHALE tribe, comprises *porpoises*, or *dolphins*, *sperm whales*, and *whales* properly so called.

28. *Whales* are not fishes. They have no scales (while fishes have); they have warm blood (fishes have cold blood); they give milk to their young, and would be drowned were they to remain longer than half an hour under water: they are *mammalia*, and *air-breathing* animals.

29. Whales have, hanging down from the roof of the mouth, several rows of the material used in commerce under the name of whalebone, each row consisting of several hundreds of fringes. Their throats are extremely narrow. The other cetaceans have teeth.

II.—BIRDS.

25. Birds, as we have already said, are easily recognized, for they all possess a beak, feathers, two wings, and two feet.

The *beak*, as you can easily see upon this fowl's head that I have prepared for the lesson, is merely a sort of horny sheath that covers over or envelops the two jaws.

The *feathers* when in a state of full development have a tube by which they are implanted in the skin; this tube is continued by a full stalk, bearing on each side a row of *vanes;* these in their turn bear smaller *vanes*, which sometimes, as is the case with goose-feathers, bear smaller ones still. All these vanes adhere together, and are woven into one another. All feathers, however, are not so complete as this.

The *wings* are generally strong enough to allow the bird to fly. Some, however, like those of the ostrich, are too short to allow their owner to rise from the ground. Some birds use their wings as fins, and with their aid swim under water.

All birds lay *eggs*, and most of them construct *nests*. The egg is composed principally of a *stony shell*, a *white* part and

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Of what is a bird's egg composed?

a *yellow* part or *yolk*. See, here are two hen's eggs, the one raw, the other cooked hard. I have broken the shell of the raw one, and its contents have run out all over the plate. Do you see in the yolk that little white speck? It is the **GERM**, and would have become a little chicken had we left it long enough to be hatched under the mother hen. I shall now take the shell off the *hard-boiled egg*, and carefully cut it in two, so that you may see the position of the yolk and the white.

When an egg is kept in a warm place for a certain length of time, the little white germ becomes a tiny bird that grows in its prison, and as it grows gradually absorbs the white and the yolk until it becomes big enough to fill the shell, which it then breaks with its beak. Thence it comes out, in some cases blind and almost motionless, like the young pigeon

FIG. 94.—Pigeon coming out of its egg. It is blind and cannot move.

FIG. 95.—Chicken coming out of its egg. It can walk.

(Fig. 94), in others lively and nimble, knowing how to seek food for itself and able to run about, like the chicken (Fig. 95), or even to swim, like the duck.

In the natural course of things, it is the mother bird that furnishes the heat necessary for *hatching* the eggs; she sits upon them, and builds the nest where eggs and young will be sheltered and kept warm. The shapes and sizes of these nests vary according to the species of the builder. But you know that eggs can be hatched by artificial heat in *boxes* made for the purpose (Fig. 96).

And this is not all I have to tell you about our feathered friends. Some of them *undertake long journeys*, very regularly,

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What is the little white speck seen in the yolk of an egg? What happens when an egg is kept warm for a certain time? In what state does the young bird come out of the egg? How is the heat generally furnished for hatching eggs? Will any other means answer?

every year; they migrate, as we say. Thus, swallows come to our country in the summer-time to lay their eggs and bring up their young; when winter draws near, and insects become scarce, they fly off again, and return to the warmer climate of the South. So do the *orioles*, the *nightingales*, and many others. Some, on the contrary, visit our country only in winter, when severe cold drives them from the far north: the wild ducks, wild geese, and swans are of this class.

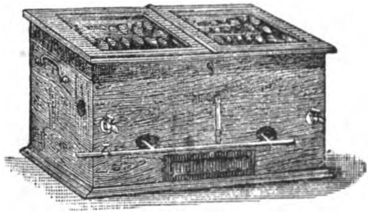

Fig. 96.—Box for hatching chickens by artificial heat. The warmth of the mother is replaced by the heat of a stove.

We will now rapidly glance at the principal groups of birds.

26. Birds of Prey.—Some birds live altogether upon the live *flesh* of other birds, of quadrupeds, or of reptiles. They are for this reason called *Birds of Prey*. They are marvellously supplied with weapons wherewith to accomplish their work of destruction: they have sharp hooked *beaks* (Fig. 97), long and piercing claws called *talons* (Fig. 98), and long pointed *wings*. They fly so swiftly and for such a length of time that a falcon once lost in the forest of Fontainebleau, in the centre of France, was found the following day at Malta, more than a thousand miles distant.

Fig. 97. Beak of a bird of prey, sharp and hooked.

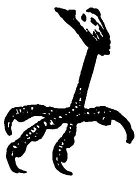

Fig. 98. Claws of a bird of prey, long piercing talons.

Some birds of prey hunt for their food in the daytime, and are for that reason called *diurnal;* others hunt after nightfall, and are called *nocturnal.*

Name some birds of passage. What name is given to those birds that feed entirely on flesh? What natural weapons have they to accomplish their work of destruction? What name is given to those birds of prey that hunt their food in the daytime? And to those that hunt by night?

Among *diurnal* birds of prey we find *vultures* (Fig. 99), that feed on the flesh of dead animals. Some very large species of these birds exist in Europe. In warm countries they render much service in clearing away dead bodies that would otherwise infect the air. The *condor* of South Amer-

FIG. 99.—Vulture.

FIG. 100.—Condor (South America).

FIG. 101.—Bearded Vulture of the Alps.

ica (Fig. 100) is the largest bird that flies; it sometimes measures from one tip of its outspread wings to the other 12 feet; the *vulture* of the Alps (Fig. 101) is almost as large. *Eagles* (Fig. 102) have stronger wings and talons than vultures; they are also bolder, and feed on live prey. The eagles of the United States are the *white-headed* or *bald eagle*, and the rarer *golden eagle*. *Falcons* (Fig. 103) are stronger still than eagles, in proportion to their size, and

FIG. 102.—Eagle.

FIG. 103.—Falcon.

FIG. 104.—Hawk.

more daring. In former times they used to be trained to hunt, and they are still so trained in Algeria and in the East. The *hawk* (Fig. 104), the *buzzard* (Fig. 105), the *sparrow-hawk* (Fig. 106), and the *kite* (Fig. 107) are much less strong.

Mention some diurnal birds of prey.

Fig. 105.—Buzzard.

Fig. 106.—Sparrow-hawk.

Fig. 107.—Kite.

Nocturnal birds of prey have a soft downy plumage which allows their flight to be quite noiseless: the openings of their

Fig. 108.—Common Owl.

Fig. 109.—Barn Owl.

Fig. 110.—Great Horned Owl.

ears are very wide, and their big round eyes are directed towards the front. They all come under the general name of *owl* (Fig. 108). Some have tufts of feathers A, B, that stand erect on each side of the head, and are called *horns;* others, such as the barn owl, have no such ornament (Fig. 109). Many species of these birds are native in our country, from the *great horned owl* (Fig. 110), almost as big as a turkey, to one (Fig. 111) about the size of a blackbird. They make not a little havoc among rats, mice, and other destructive animals of small size; this should induce people to protect them instead of nailing them up on barn doors, as is the stupid custom in some places.

Fig. 111.—Small kind of Owl. Size of a blackbird.

Name some nocturnal birds of prey. Why should they not be destroyed?

27. Parrots.—*Parrots* (Fig. 112) are characterized by their short, clumsy beak, their fleshy tongue, which allows them to articulate words, and their toes two turned forward and two backward, allowing them to climb with ease. Their remarkable intelligence has entitled them to be called the *feathered monkeys*. Like monkeys, they are natives of warm countries, and their noisy and gaudy bands people the intertropical forests of both hemispheres.

FIG. 112.—Ara. Parrot.

28. Pigeons.—Pigeons in their natural state are neither of great variety nor of a great number of species. In this country we have the *turtle-dove* (Fig. 113) and the *wild pigeon*, besides many domestic pigeons that have been brought from Europe.

FIG. 113.—Turtle-Dove.

29. Gallinaceans.—The name of *Gallinaceans* (from the Latin *gallina*, the hen) has been given to the birds of this group on account of their greater or less resemblance to the *hen*, which has been taken as a type. They are grain-eating birds. Our hens are supposed to have originally come

FIG. 114.—Pheasant.

FIG. 115.—Peacock.

FIG. 116.—Guinea-Fowl.

from India, as well as the *pheasants* (Fig. 114), and *peacocks* (Fig. 115). The *Guinea-fowl* (Fig. 116) came from Africa, and the *turkey* (Fig. 117) and *prairie-chicken* (Fig. 119) are natives of America. In our country are also to be found the common *partridge* and the *quail* (Fig. 118).

FIG. 117.—Turkey.

FIG. 118.—Quail.

FIG. 119.—Prairie-Chicken.

30. Wading Birds.—The *Wading Birds* are so called on

FIG. 120.—Stork.

FIG. 121.—Heron.

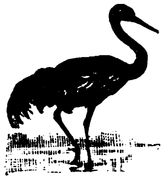

FIG. 122.—Crane.

FIG. 123.—Lapwing.

FIG. 124.—Curlew.

FIG. 125.—Snipe.

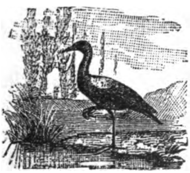

FIG. 126.—Water-Hen.

FIG. 127.—Bustard.

account of their long, naked legs. Most of them live in marshy places, and wade through mud and water; they are

usually provided with long necks and beaks, so formed as to enable them to catch, notwithstanding their long legs, the small animals on which they feed. Those best known in our country are the *heron* (Fig. 121), the *crane* (Fig. 122), the *snipe* (Fig. 125), the *water-hen* (Fig. 126), the *plover*, the *rail*, the *woodcock*, the *sandpiper*, etc. The *stork* (Fig. 120) is common in Europe, and in Holland makes its nests on the house-tops; in Europe are found also the *lapwing* (Fig. 123), the *curlew* (Fig. 124), and the *bustard* (Fig. 127).

31. Ostriches.—*Ostriches* are large birds, whose wings,

Fig. 128.—Ostrich (Africa).

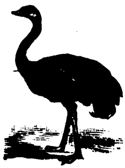

Fig. 129.—Rhea (America).

Fig. 130.—Cassowary (Australia).

although too short for flight, help them to run with great rapidity. They are so strong that they can carry a man on their back.

Fig. 131.—Skeleton of a large bird from New Zealand. Exterminated. Height, about 10 feet.

The *ostrich* is a native of Africa: it has but two toes (Fig. 128). It attains the height of more than 7 feet. The *rhea*, a South American ostrich (Fig. 129), is of smaller size, and has three toes. The *cassowary* of Australia and Borneo (Fig. 130) is larger than the rhea, but of a clumsier shape.

Great in size as these birds are, they seem quite small beside some of their species, closely related to the cassowary (Fig. 131), which the natives of Madagascar and New Zealand have exterminated. They are nowhere to be found at the present day, and all that remains to tell what they were are a few of their bones and some of their eggs.

But what eggs they are! One single egg is equal to about six ostrich-eggs, or, to come nearer home, to a hundred and fifty hen's eggs.

32. Palmipeds.—*Web-footed Birds.*—These have, as their name indicates, *palmated or webbed feet* (Fig. 132); that is to say, their toes are united to one another by a skin or web. This allows them to swim easily. Look at this duck's foot: when the bird draws it forward, it folds it up nicely so as to pass through the water without forming the slightest obstacle; on the contrary, when pushed backward, it spreads itself out, offers a resistance, and the bird is thereby propelled forward.

Fig. 132. A webbed foot.

Ducks (Fig. 133), *geese* (Fig. 134), and *swans* (Fig. 135) are Palmipeds that swim to perfection and fly very well, but walk very badly. They have a broad bill provided with a sort of tiny saw that fulfils for

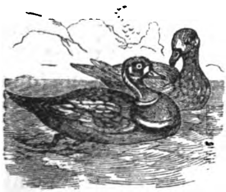

Fig. 133.—Duck.

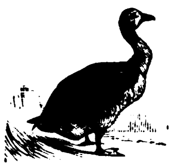

Fig. 134.—Goose.

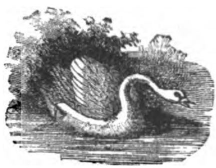

Fig. 135.—Swan.

them the purpose of teeth. *Sea-gulls* (Fig. 136), that live almost always on the sea-shore, and the enormous *albatross* of

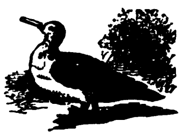

Fig. 136.—Sea-Gull.

Fig. 137.—Albatross.

Fig. 138.—Pelican.

the South seas (Fig. 137), have pointed bills; they also are excellent fliers. The *pelican* (Fig. 138) and the *cormorant*

(Fig. 139) are even more completely web-footed than the foregoing, for the web envelops not only the three foretoes, but also the first or great toe.

Upon the shores of the Northern seas the *awks* (Fig. 140) are to be seen in myriads; and in the South seas the *penguins* (Fig. 141) are quite as numerous. Neither species can fly. This is not because their wings are too weak to carry them, as is the case with the ostrich; they are, on the con-

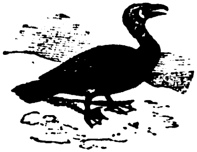

Fig. 139.—Cormorant.

Fig. 140.—Awk.

Fig. 141.—Penguin.

trary, very strong; but they have no real feathers upon them, and the bird uses them only as fins, to swim under water.

33. Passerines.—*Sparrows.*—This name is given to a great number of genera of birds that are neither birds of prey nor palmipeds, etc. The Passerines, in fact, include most of the small birds in existence.

Some members of this tribe have two toes in the front, and two others turned backward, which enables them to climb admirably along the trunks of trees. Such is the *woodpecker* (Fig. 142), very unjustly accused of damaging the trees of our forests while in reality he merely searches the holes that the insects have already made. Some others have a hooked beak like birds of prey. Such is the *shrike.* Others have a delicate beak, sometimes pretty long, by which they manage very cleverly to catch insects. Such are the *blackbirds*, *warblers*, *orioles*, and *robins* of our country; also our *humming-birds*, so brilliant, and so tiny that the smallest is not bigger than a large bee, etc. Others have a widely-opening beak, well adapted for catching gnats. This is the case with the *swallows.* Others, again, have a strong, short, thick beak, with which they eat grains of all sorts.

These are the *lark*, the *house-sparrow*, the *chaffinch*, the *titmouse*, the *bullfinch*, the *reed-bird* or *bobolink*, etc. Others

FIG. 142.—Woodpecker.

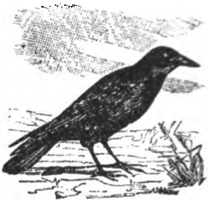

FIG. 143.—Crow.

can use their powerful beaks like a sort of pickaxe, with which they turn up the earth and tear to pieces dead bodies. Such are the *magpies*, *jays*, *crows*, etc. (Fig. 143). In this country there are about two hundred species of this very interesting group. Some of them are excellent songsters, such as the *thrush* and the *mocking-bird*.

SUMMARY.—BIRDS.

1. **Generalities** (p. 45).—Birds have a horny *beak*, feathers, two feet, two wings; they lay *eggs*.
2. Eggs are enclosed in an earthy shell, and consist of a white part and a yolk. In the yolk floats a tiny white speck called the *germ*, which will become the chicken when the egg is hatched.
3. In the natural course of things it is the hen that furnishes the heat necessary for the *hatching* of the egg; but eggs can be artificially hatched in boxes made for the purpose.
4. **Birds of Prey** (p. 47).—BIRDS OF PREY have a sharp, hooked beak, toes provided with long, sharp nails, called *claws* or *talons*, long and pointed wings. They fly with great rapidity.
5. Some hunt during the daytime, and are called *diurnal;* others pursue their prey after nightfall, and are called *nocturnal*.
6. Among diurnal birds we find *vultures*, that feed on dead animals; *eagles*, that feed on live prey; *falcons*, that were formerly trained for the chase.
7. Among the nocturnal birds of prey are *owls*.
8. Owls of all descriptions destroy rats and mice: they ought, therefore, to be protected.
9. **Parrots** (p. 50).—PARROTS are to be found only in warm climates.
10. **Pigeons** (p. 50).—PIGEONS, natives of our country, are the *wood-pigeon* and the *turtle-dove*.
11. **Gallinaceans** (p. 50).—Under this head are generally grouped birds

that more or less resemble the hen: *pheasants, peacocks, Guinea-fowls, turkeys, partridges.*

12. Wading Birds (p. 51).—Most WADING BIRDS are perched upon long, slender legs. Those best known are *storks, herons, cranes, snipes.*

13. Ostriches (p. 52).—OSTRICHES are large birds. The species found in Africa sometimes stands seven or more feet high. Their wings are too short to be used in flight, but they run very swiftly.

14. Palmipeds (p. 53).—PALMIPEDS, or *web-footed* birds, have, as their name indicates, *palmated* or *webbed feet;* that is to say, their toes are enveloped or united by a film or web. This allows the birds of this tribe to swim with great ease. *Ducks, geese,* and *swans* are Palmipeds.

15. Sparrows (p. 54).—Under this name is included a great variety of species: *blackbirds, warblers, nightingales, swallows, larks, finches, crows,* etc.

III.—REPTILES.

34. In their shape and outward appearance *Reptiles* differ very considerably from one another. There are *Tortoises,* that have a horny beak like a bird, four feet, and a sort of horny house in which their body is enclosed (the upper part of this box is called the *carapace*, the lower part the *plastron*); *Lizards*, that have teeth and limbs, but no carapace; *Serpents*, that have neither carapace nor limbs. All reptiles lay eggs, somewhat similar to those of birds, only the shell, instead of being earthy and brittle, is horny and elastic.

35. Tortoises.—Some tortoises live on land; others are to be found in marshes and in fresh water; others, again, called *turtles*, live in the sea (Fig. 144). They are encased in a

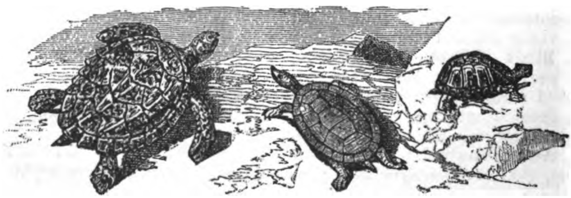

FIG. 144.—Sea Tortoise, or Turtle. Fresh-water Tortoise. Land Tortoise.

flat carapace which offers but little resistance to the water through which the animal moves by the aid of its long, flattened, paddle-like limbs. Upon some parts of our coasts great multitudes of these turtles resort to deposit their eggs.

There they are captured for their flesh, to make soup, and for their shells, which furnish the valuable tortoise-shell.

The land *tortoises* have short limbs and more convex carapaces, which last are so strong and resisting that a man may stand upon the back of a tortoise 4 inches long without harming it. In Africa some are found 3 feet long.

Fresh-water tortoises are, in shape, intermediate between the turtle and the land tortoise.

36. Lizards.—The largest of this group is the *crocodile* (Fig. 145), powerful enough to be very formidable even to

Fig. 145.—Crocodile. Some are 24 feet long.

mankind. The large rivers of Africa, Asia, and South America swarm with them, and some attain a length of more than 24 feet. The *alligator* of the rivers of the southern United States has partially webbed feet: it is very closely related to the crocodile.

Among the numerous species of the lizard tribe the most curious is the *chameleon* (Fig. 146). This strange creature

Fig. 146.—Chameleon. Changes color.

Fig. 147.—Lizard. Its tail grows again after having been broken off.

is very common in Syria and on the southern coasts of the Mediterranean. It owes its world-wide celebrity to its

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Name a large lizard which is very formidable to man.

faculty of rapidly changing color according to circumstances. Anger or calm, sun or shade, have influence upon it, and cause it to become green, yellow, black, etc. The *Gila monster* of Arizona is a lizard more than a foot long: it is a sluggish animal, but it secretes a venom or poison and its bite is dangerous.

Some lizards present a strange phenomenon: their tail, brittle and easily broken, lives for a considerable length of time after being separated from its bearer's body; and, more than that, *the lost tail is in a comparatively short time replaced by another, similar to the amputated one.* This is certainly very convenient, and a great pity it is that mankind cannot renew lost limbs after the same fashion.

The *slow-worm*, or *blind-worm*, although altogether deprived of limbs, is also a lizard. It is so very brittle that one can scarcely touch it without breaking its tail. The *glass snake* of the United States is a lizard presenting a similar peculiarity.

37. Serpents.—There are some serpents whose bite, accompanied by the emission of a liquid poison called *venom*, is

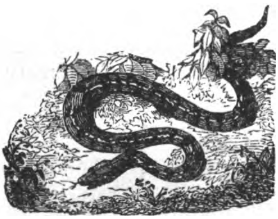

FIG. 148.—Boa of South America. Sometimes measures 36 feet.

FIG. 149.—Head of a garter-snake.

FIG. 150.—Head of a viper.

always dangerous, and often even mortal: they have been, therefore, deservedly called *venomous serpents.*

Others do not bite, but coil themselves tightly around their

What peculiarity does the tail of the lizard present? What name is given to serpents whose bite might prove deadly?

prey; such are dangerous only when of very considerable size. The *boa* of South America (Fig. 148), the *python* of Africa, and some other species, are of this class; some have been known to attain the length of 36 feet. These enormous reptiles, by the mere pressure of their tightened folds, can kill an ox with the greatest ease, and man is but small game to them.

Our *garter-snakes* (Fig. 149) are much smaller, and quite inoffensive. The *snakes* of the United States are all of small dimensions, the longest rarely attaining a length of 6 feet.

In Europe but one venomous serpent exists, the *viper* (Fig. 150), and it is one of the least dangerous. The venom is a liquid that accumulates in a small pouch (A, Fig. 151) situated at the root of a long and very sharp tooth B, through which runs a curved canal. When the animal bites, the tooth presses on the pouch A, and a drop of the venom enters the canal and penetrates with the tooth into the wound. The extraction of this tooth (there is one on each side) renders the bite perfectly harmless; and this is how jugglers allow themselves to be bitten by deadly serpents to the great amazement of the spectators.

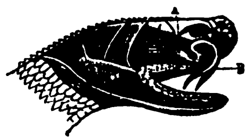

FIG. 151.—Head of a viper.
A, pouch where the venom accumulates.
B, tooth very pointed and pierced by a passage through which the venom flows.

But the venom of the viper is weak compared to that of the *horned adder* of the African deserts, the *fer de lance* of Martinique, the *rattlesnake* of our country, or the *cobra* of India. The bite of any of these species is almost always rapidly fatal to man. Four venomous serpents exist in the United States, the *water-moccasin* and *harlequin-snake* of the South, the *copperhead*, and the *rattlesnake*. The last is the most dangerous; the end of its tail is provided with curious horny rings with which it makes a loud rattling noise when irritated

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Does the boa destroy its victims in the same manner as venomous serpents? Mention a venomous serpent of Europe. Where does the venom accumulate? What peculiarity is there about the pointed tooth of a serpent? By what means do they use the venom? Are there any serpents still more dangerous than vipers? What venomous serpents are natives of the United States? What effect is produced by the venom of serpents? What is said of the cobra of India?

or disturbed. The arrangement of the rattlesnake's poison-fangs is like that of the viper's.

The bite of a venomous serpent is rapidly followed by fever, great swelling, and even mortification. The venom is not poisonous when swallowed, and in case of a serpent-bite, if there be no sores about the mouth or lips, the poison should be sucked from the wound.

In the course of the year 1875 the cobra caused the death of 26,000 persons in British India. The whole country swarms with them. This reptile has no warning rattle like that of the rattlesnake, but can stealthily fall upon the unwary passer-by.

SUMMARY.—REPTILES.

1. Reptiles differ greatly in shape from one another. The group comprises *Tortoises, Lizards*, and *Serpents.*

2. Tortoises (p. 56).—Tortoises and turtles have a horny beak, similar to that of birds, four feet, and a carapace, in which their bodies are enclosed.

3. Some of these animals live on the land, some in marshy places and fresh water, others in the sea. These last sometimes attain the length of six feet.

4. Lizards (p. 57).—The largest of the *Lizard* family are the *crocodiles*, which sometimes attain the length of twenty-four feet. These animals are dangerous to mankind. The *alligator* much resembles the crocodile.

5. The *chameleon* of Algeria can change its color according to circumstances, as it is angry or calm, in full sunlight or in the shade.

6. Common lizards have very brittle tails, easily separated from the body; but these appendices grow again, and attain their primitive dimensions.

7. Serpents (p. 58).—Some *serpents* are venomous, others are not so.

8. Among serpents that have no venom we find the *boa* of South America and the *python* of Africa. These species sometimes attain the great length of thirty-six feet; they are able to kill even large animals by coiling themselves around their victims and thus suffocating them.

9. The *garter-snake* of our country is quite harmless.

10. It is not so with the *viper*, the *water-moccasin*, the *copperhead*, and the *rattlesnake*, whose venom causes fever, great swelling, sometimes mortification, and very often death.

This venom is contained in a sort of pouch or gland situated at the root of a long, sharp, hollow tooth. When the animal bites, the tooth presses on the pouch, and a drop of venom enters the canal that runs through the tooth, and penetrates with the tooth into the wound.

IV.—AMPHIBIANS.

38. Metamorphoses of Amphibians.—We have already seen that the animals belonging to this group are *aquatic* when young, and *aerial* when full-grown. Between these two stages of life they undergo remarkable changes in their shape, as well as in their mode of life: these changes are called *metamorphoses.*

The most complete examples of metamorphoses are presented by *toads* (Fig. 152), the common *frogs*, and the *green frogs* or *tree-frogs.*

You have all certainly seen frogs' eggs (Fig. 153, A), and you know that they have no hard shell, but are soft and

Fig. 152.—Toad.

Fig. 153.—Transformation of a frog's egg.
A, frog's egg. B, C, D, tadpoles.
E, tadpole become frog. F, frog.

coated in a slimy envelope. After a certain time the egg gives birth to a little black creature B, which in the space of a few days becomes excessively brisk and lively. It grows rapidly, and displays a long fish-like tail, with a body and head all in one big ball C, D, E. It has no limbs whatever; shortly, however, legs and feet make their appearance, the hind ones first. As the legs grow, the tail gradually diminishes, until at last the animal is in possession of four full-sized legs, and has entirely lost both its tail and its gills, the place of these latter being taken by lungs. The *tadpole* has become a frog, or a toad, E, F. Originally *aquatic*, it has become *aerial;* the *grass-eater*, or *herbivorous* creature, has

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What does the word *Amphibian* mean? What phenomena do these animals present? What is the first state of the frog? What comes out of the egg? What change soon takes place in the little animal? How do the feet make their appearance? What becomes of the tail? Explain the different transformations respecting respiration and food.

become a *flesh-eater*, or *carnivorous animal.* This is strange indeed, and certainly very interesting.

Fig. 154.—Triton, or Water-Newt.

Fig. 155.—Salamander.

Other Amphibians undergo less complete metamorphoses. The *salamander* of Europe (Fig. 155), for instance, and the *Triton* (Fig. 154), which we call the *water-newt*, retain their tail all their life. Some tropical Amphibians are snake-like, and have no limbs.

39. Usefulness of Toads.—Toads do harm only to insects, worms, and snails, of which they devour great numbers; yet notwithstanding all this the poor creatures are often cruelly and stupidly destroyed. It will undoubtedly not a little astonish you to learn that great numbers of these useful but disregarded animals are sent from Europe to Australia, to help keep the gardens free from noxious and destructive guests, such as snails, insects, etc.

Venom of Toads.—But, while I advise you to spare the toad, I warn you to avoid touching it. Look at this one (Fig. 152) which I caught for our lesson, and which I touch only with a pair of tongs. This way of handling it is evidently not at all to its taste, and has made it angry. You can see all over its back, and especially about its neck, a great many little drops of liquid oozing out of its skin. That is *venom, and is most pernicious.* If a drop of that milky-looking substance were to be put under the skin of a fowl it would be sufficient to kill it. You see it is not to be played with; but if they are not irritated toads can be handled without harm.

What services do toads render us? How does the toad secrete its venom? What effect does this venom produce when introduced under the skin of a chicken?

All Amphibians have more or less venom in their skin. If you should happen to rub your eyes after handling a frog, you would not fail to feel them smart severely.

SUMMARY.—AMPHIBIANS.

1. **Metamorphoses** (p. 61).—Some AMPHIBIANS, *aquatic* when young, *aerial* when full-grown, undergo changes in form which are called *metamorphoses*.

2. When young they are *tadpoles;* have a large head, a long tail, but no limbs. Afterwards they become *frogs* or *toads;* their tails and gills disappear, and they have two pairs of limbs.

3. Toads secrete a venom, which they cannot, however, inoculate. By way of compensation, they render us service by devouring insects, worms, and slugs.

V.—FISHES.

40. *Fishes are exclusively aquatic during their whole life.* Out of water they inevitably perish, sometimes very rapidly, sometimes slowly, according to their species.

41. Some fishes live in *fresh water*, others in the *sea*. Were a fresh-water fish to be suddenly plunged into salt water it would rapidly die. But if the change were made by degrees, and with precaution, it would get accustomed to its new condition of life.

This fact explains the faculty that migratory fish have of living alternately in fresh and in salt water. The *salmon* (Fig. 164), the *sturgeon* (Fig. 156), the great *lamprey* (Fig. 168), and the *shad*, ascend yearly from the sea to the rivers, where they remain several months and deposit their eggs; the young ones go down to the sea after a length of time that varies according to the species. However, *eels* go to lay their eggs in sea-

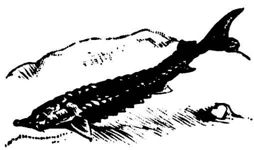

FIG. 156.—Sturgeon.

Are toads the only Amphibians that have venom under their skins? Mention a characteristic peculiar to fishes. Name some fish that go from the seas to the rivers to spawn.

water: those kept all their lives in ponds never lay eggs at all.

42. Structure of Fishes.—Nothing can be more varied than the outward shape of fishes. The most common is that of a flattened spindle (Fig. 157); some, such as the *eel*, resemble serpents (Fig. 158); some are flattened sideways, like the *flounder* (Fig. 159); others are spread out, like the *skate* or *ray* (Fig. 160).

Almost all of them have *fins* (Fig. 161); that is to say, membranes stretched upon bony ridges of greater or less

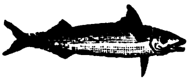

Fig. 157.—The typical shape of fishes. Mackerel.

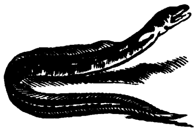

Fig. 158.—Eel. Goes to the sea to lay its eggs.

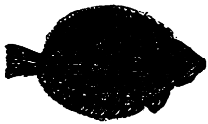

Fig. 159.—Flounder. Flat fish. Length, 10 inches.

hardness and size. These *fins direct the course of the fish through the water; the tail by its motion from right to left*

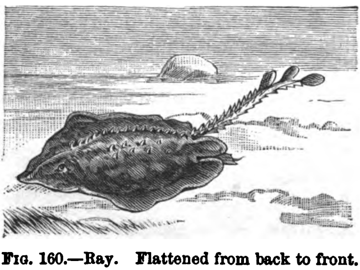

Fig. 160.—Ray. Flattened from back to front.

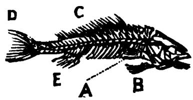

Fig. 161.—Skeleton of a goldfish.

A, pair of fins, representing the arms.
B, pair of fins, representing the legs.
C, dorsal fin.
D, caudal fin.
E, anal fin.

propels it forward, as you may observe by looking attentively at this goldfish.

Describe the leading forms of fishes. What is the use of the fins and tail in swimming?

Let us look closely at the other fins. See, there are two pairs, the foremost, A, representing the arms, the others, B, the legs. Others exist on the mid-line of the body: one, C, on the back (the dorsal fin), one, D, at the tail (the caudal fin), the other, E, behind the intestinal opening (the anal fin).

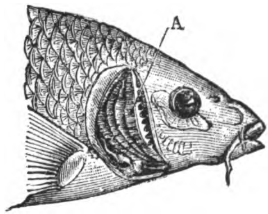

FIG. 162.—The Gills exposed. Fishes breathe by the gills.

All fishes have *gills*, A (Fig. 162), *by which they breathe.* You can see them, quite red and full of blood, on each side of the head, overlapped by a sort of flap that regularly and alternately opens and shuts.

43. Commonest Species.—The kinds of *Fishes* are extremely numerous, some thirteen thousand species being known to exist. In the *fresh water* of our country are to be found the *carp*, *bass*, *rockfish*, *catfish*, *roach*, etc.; also the *pike* (Fig. 163), *salmon* (Fig. 164), *trout*, *perch*, *stickleback*, *eel* (Fig. 158), etc.

Sea-Fish are much more varied in shape, and also more numerous in species, than those of fresh water.

The *herrings* pass the greater part of their lives in the deep parts of the northern seas. When the milting season comes on, they gather together in great *bands*, or *shoals*, of millions and millions, and ap-

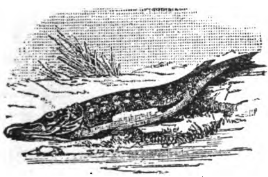

FIG. 163.—Pike. Fresh-water fish.

FIG. 164.—Salmon. Fresh-water fish.

proach the shores of Great Britain and France, followed in their wake by large fishes, dolphins, and sea-birds that come to prey upon them. Man is, however, the great destroyer of the

Enumerate the fins of the goldfish. What is the use of the gills? Where does the herring pass the greater part of its life? Where and under what circumstances do our fishermen meet with it?

herring tribe. Whole fleets are laden with the spoil. Fortunately, each female herring lays an immense number of eggs, about 50,000, otherwise the race would soon disappear from the seas.

The *sardine*, an inhabitant of the Mediterranean Sea and the Atlantic, is a sort of small herring that lives in *shoals*, like its bigger relative which we have just spoken of.

The *cod* (Fig. 165) is a sea-fish also, and for its capture immense fisheries, that employ hundreds of vessels, have been organized in the northern seas, especially in the waters off Newfoundland.

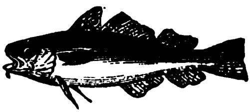

Fig. 165.—Cod. Sea-fish.

Of the *Flatfishes*, the most frequently met with on the coasts of the United States is the *flounder* (Fig. 159). Some of this group ascend rivers for a considerable distance.

Mackerel (Fig. 157) visit our coasts in great numbers during the summer; the *tunny-fish*, or *Spanish mackerel*, which, according to Dr. John Davy, has a temperature higher than that of the water in which it lives, is sometimes 13 to 18 feet long.

One species of the *shark* kind (Fig. 166) is noted above all the rest of its race for its great size and its great ferocity.

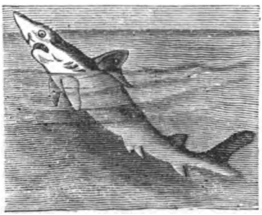

Fig. 166.—Shark. Sometimes measures 40 feet. Ferocious fish. Mouth under the head.

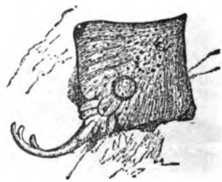

Fig. 167.—Skate. Mouth under the body.

What is the sardine? Where have great cod-fisheries been established? Which is the most ferocious of all fishes?

This dreaded sea-monster, sometimes 40 feet long, swallows almost everything it meets with; it destroys enormous numbers of fishes, and could snap off a man's leg as easily as you could bite through a bit of apple. For this purpose it is provided with a great mouth, situated not at the end of its snout, as is the case with other fishes, but *under its head*, and set with several rows of formidable triangular—that is, three-cornered—teeth. The gills have five slits, instead of the one existing in ordinary fishes.

Suppose you were to flatten out a shark, you would have an animal very like a *skate* (Fig. 167).

The *lamprey* (Fig. 168) bears great resemblance to the eel, but it has no side-fins. On each side of the neck it has seven gill-slits, and its mouth is a sort of circular opening, which is set with sharp teeth, and which it uses as a sucker, thereby fixing itself firmly to stones, etc.

FIG. 168.—Lamprey.

There are a great many other curious fishes that we might pass in review, but we must leave sufficient time for the study of other subjects.

SUMMARY.—FISHES.

1. Fishes (p. 63) are absolutely *aquatic*. Out of the water they inevitably perish.

There are fishes that live in the *sea* only, others that live exclusively in *fresh water*. Certain species *migrate* from the sea into rivers, and others from rivers to the sea.

2. The form of fishes is extremely varied. Some, the most numerous, bear a resemblance to a flattened spindle; others, such as the *eel*, are not unlike the serpent; some are flattened sideways, like the *sole;* others are flattened from back to front, like the *skate*.

3. All fishes have *gills*, by which they breathe. Almost all have *fins*.

4. The most dangerous of fishes is the *shark*, which attains at times the length of forty feet. It is provided with a great mouth, situated not at the point of the snout, but *under the head:* this mouth is armed with several rows of formidable triangular teeth, with which the monster is able to snap off the thigh of a man with the greatest ease.

Where is the shark's mouth placed?

II.—ANNULATES.

You all remember the meaning of the word *annulate*. The bodies of the members of this group seem to be composed of a series of RINGS that are jointed together, although these rings are not always very like one another.

The following are the groups into which Annulates have been divided: *Insects*, *Spiders*, *Millepeds*, *Crustaceans*, and *Worms*.

44. Insects.—First in order we find the INSECTS, *that have* SIX FEET, like this butterfly. Their body is, as you can see, composed of three parts (Fig. 169), the *head* A, the *thorax* B, and the *abdomen* C. The head bears two horns or feelers D, properly called *antennæ*, and two large eyes, which seem, if you examine them with a magnifying-glass, to be cut *with facets*, like precious stones (Fig. 170). The six feet are borne by the thorax; and it is the thorax also that bears the four wings of our butterfly, and the two wings of yonder fly (Fig. 171). Antennæ, limbs, and wings, and all similar organs, are called *appendages*. None of these being found on the abdomen, we therefore say that it has no appendage.

Fig. 169.—Body of an insect (butterfly). A, head; B, thorax; C, abdomen; D, antennæ.

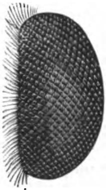

Fig. 170.—Insect's eye, as if cut with facets (greatly magnified).

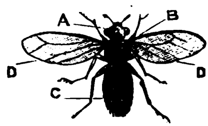

Fig. 171.—The six legs and two wings belong to the thorax. A, head; B, thorax; C, abdomen; D, wings.

Many insects undergo metamorphoses quite as complicated

What is the definition of the word *Annulata*, that is given to a very important group of insects? What characteristic is common to the *Insect* group? Into how many parts are the bodies of insects divided? What name is given to the two feelers? What peculiarity do the eyes of insects possess? On what part of the body are the six feet and wings placed?

as those of the frog. You have all had occasion to observe those of the butterfly (Fig. 172). When newly out of the egg, it is a tiny *caterpillar* A, which grows very rapidly and casts its skin four times. The fifth time its skin becomes thick and hard, and the caterpillar seems to have fallen into a deep sleep, after having, in some cases, spun a silky bed, called a *cocoon*, in which it shuts itself up. In this state it takes

FIG. 172.—Metamorphoses of the Butterfly.
A, Caterpillar. B, Chrysalis. C, Butterfly.

the name of *chrysalis*. At the last, the sixth change of skin, the chrysalis bursts and ushers into sunlight a winged butterfly C, ready to lay its eggs. This is what is called a *complete metamorphosis*.

Grasshoppers also undergo metamorphoses, for the *young ones have no wings when born*, but at each casting of their skin the wings gradually grow, and after the sixth change the insect attains its perfect state without having passed through the deep sleep of the chrysalis, or any such extraor-

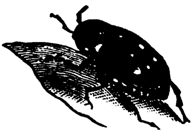

FIG. 173.—Beetle.

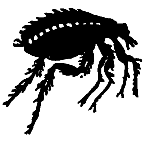

FIG. 174.—Flea (magnified).

FIG. 175.—Bee.

dinary change as the butterfly has done. This is what is called *incomplete* or *partial metamorphosis*. *Flies*, *beetles*

Under what form does the butterfly come out of its egg? What becomes of the caterpillar at its fifth transformation? What name is given to it in this state? What becomes of the chrysalis after the sixth change? What name is given to these different changes? What are the metamorphoses of the grasshopper? What name is given to these changes? Name some other insects that pass through a complete metamorphosis.

(Fig. 173), *fleas* (Fig. 174), and *bees* (Fig. 175) undergo complete metamorphoses. *Dragon-flies*, *gnats* (Fig. 176), and *bugs* (Fig. 177) undergo but partial ones.

The mouth of an insect is not constructed like ours or like that of any vertebrate: its jaws or mandibles, instead of moving up and down, are placed laterally, and move

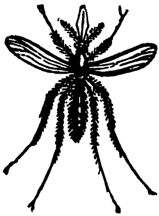

Fig. 176.—Gnat (magnified).

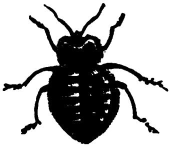

Fig. 177.—Bedbug (magnified).

Fig. 178.—Head of beetle (magnified) seen from underneath.

from RIGHT TO LEFT. Look at this beetle; see its powerful jaws (Fig. 178), which enable it to lay hold of and tear to pieces other insects, on which it feeds. This *may-bug*

Fig. 179.—Head of may-bug (magnified), seen from underneath. A, superior extremity.

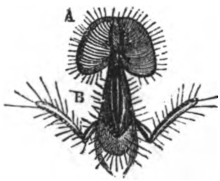

Fig. 180.—Trunk of fly (magnified). A, sucker; B, sheath of sucker.

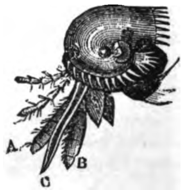

Fig. 181.—Head of flea (magnified). A, B, sheath of sucker; C, pointed style.

(Fig. 179), that lives on leaves, has much weaker mandibles. Flies have a short but strong *proboscis* B (Fig. 180), well

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Mention some other insects whose metamorphoses are incomplete. How do the jaws of vertebrate animals move? Give two examples. What shape has the fly's jaw? the flea's? the bug's? the butterfly's?

adapted for sucking. Fleas and bugs have *sharp styles* C (Fig. 181), with which they pierce the skin in order to suck the blood of their victim. The butterfly has a long, *coiled-up proboscis* (Fig. 182), which it unrolls and plunges into flowers in order to obtain the sweet liquids contained in the perfumed calyx.

The group of Insects is the most numerous in species of all the animal kingdom; their number amounts to above one hundred and fifty thousand.

There are very useful species among them, such as the

Fig. 182.—Head of butterfly (magnified).

Fig. 183.—Phylloxera without wings (greatly magnified).

Fig. 184.—Phylloxera with wings (greatly magnified).

silk-worm, the *bee*, the *cochineal-insect*, etc.; but there are some very noxious ones, also, such as *caterpillars*, *may-bugs*, *grasshoppers*, *potato-bugs*, and many others.

The most destructive and terrible of all is a so-called plant-louse, a native of America, that was carried across to France about twenty years ago. It is called the *phylloxera* (Fig. 183). So tiny is it that one can scarcely discern it with the naked eye. *It lives upon the delicate roots of the vine, which it sucks and exhausts* so that the much-prized plant pines away for three or four years and finally perishes. It multiplies with prodigious rapidity, and millions of these tiny but terrible invaders are in a short time ready to leave the parent colony, and wingless travel on under ground to look out for a new

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Mention the leading kinds of insects. What is the phylloxera? On what does it live? What effect does it produce? The phylloxera being so small, why is it so dangerous?

home. Besides these, there are also winged (Fig. 184) members of the family, which go forth, borne by the wind, to lay their eggs at a distance. No wonder, then, that countless legions of phylloxera have already infested the greater part of the vineyards in the south of France, notwithstanding the active warfare directed against them.

45. Spiders.—After the Insects we come to SPIDERS (Fig. 185). All of these possess EIGHT FEET, as I have already told you. The head and the thorax are blended into one body, to which are attached the eight feet. They never have wings.

FIG. 185.—Spider, 8 feet, head and thorax blended in one.

The spiders, properly so called, have

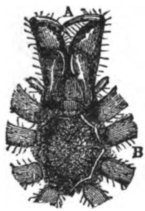

FIG. 186.—A, poison-hooks of the spider (magnified); B, thorax seen from underneath, showing where the 8 legs are attached.

FIG. 187. — Scorpion. The poison-apparatus is at the end of the tail. Length, 3 inches.

FIG. 188.—Itch insect, a tiny spider, invisible to the naked eye. Seen from underneath.

in their mouth relatively large poison-hooks (Fig. 186), with which they puncture, benumb, and kill the insects on which they prey. Some species in South America are about the size of a man's thumb, and are able to seize and suck to death little birds. The *tarantula* of the Southwestern United States is almost as large as the above-mentioned species, and inflicts a bite that is dangerous even to man.

Most spiders have on the extremity of the abdomen a sort of *spinning apparatus*, from which they draw a very fine but

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How many feet have spiders? What is the nature of the hooks that the spider has at its mouth? Where is the spinning apparatus of the spider placed?

wonderfully strong thread, and with it many species weave artistically complicated webs. This web the spider stretches out, then lies in wait for the heedless insects that may happen to rush into the snare. As soon as the insect is entangled, the spider pounces upon it, benumbs it by puncturing it with its venomous weapon, and fetters the prisoner with a winding silken thread.

In warm countries, under stones in dry places, are often to be found long-bodied creatures somewhat akin to spiders. Their antennæ, or feelers, are terminated by strong pincers: they spin no thread, and their poison-apparatus is situated at the tip of their tail, instead of being in the mouth as is the case with spiders. These are *scorpions* (Fig. 187). Their sting occasions severe fever to mankind, and is fatal to small animals.

The loathsome disease known under the name of the *itch* is caused by a *very small animal* (Fig. 188), *a sort of spider, scarcely visible to the naked eye, which burrows under the skin*, producing thereby insufferable itching. In former times people thought this was caused by impurity of blood, and the unfortunate patients were bled and physicked with more zeal than success. It has since been ascertained that the only cause of this disease is the presence of these minute insects under the skin. Sulphur ointment rubbed on the infected parts kills the insects and dispels the distemper. You thus see how useful science is, even in little things, and how important it is to be sufficiently acquainted with one's enemy.

46. Millepeds.—The MILLEPEDS and CENTIPEDES, so called with exaggeration, have at least twenty pairs of feet (Fig. 189). In their case the head is distinct from the rest of the body. Properly speaking, their body has neither thorax nor *abdomen*, but consists simply of a series of rings, each of which, according to the species, bears one or two pairs of legs. Many centipedes are

FIG. 189.—Milleped.

What does it produce? Why do spiders spread their webs? By what animal is the itch produced? To what cause was the itch formerly attributed? How was it treated? How is it now treated? What are the characteristics of the Millepeds?

to a certain extent venomous, and produce painful sores on parts of the body over which they have passed.

47. Crustaceans.—All the Articulata with which I have hitherto entertained you are *aerial* and live upon land. On

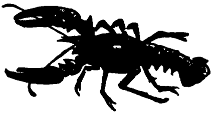

FIG. 190.—Crayfish (crustacean).

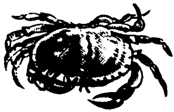

FIG. 191.—Crab (crustacean).

the contrary, *crayfish* (Fig. 190), *lobsters*, *crabs* (Fig. 191), and animals akin to them are almost all aquatic. Because of their crusted skins, they are named *Crustaceans* (from the Latin *crusta*, a crust). Many insects—for example, our dragon-flies—are, like the Amphibia, aquatic when young. On the other hand, among Crustacea the land-crabs are largely, and the wood-lice wholly, air-breathers living on land.

48. Worms.—These animals have no distinct head nor armor. No worm-like animals even have jointed legs, but some have either bristles, called *setæ*, or *suckers*, which serve the purpose of legs, viz., locomotion.

The *lumbric*, or *earth-worm*, is the best known of all. See,

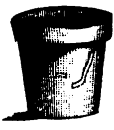

FIG. 192.—In less than a year you will find two entire worms.

FIG. 193.—Sucker of leech (seen from underneath).

here is one the gardener cut in two when digging in the garden. If you put those two halves in a flower-pot, with earth kept constantly moist (Fig. 192), *in less than a year you*

What distinguishes worms from insects? What becomes of an earth-worm when cut in two and placed in a pot of damp soil?

will find two whole worms; a head will have grown on the half that had but a tail, while a tail will have grown to the half that had none.

Leeches have a sort of *sucker* (Fig. 193), by which they fix themselves firmly. The kind used for medical purposes have teeth strong enough to pierce the human skin.

Both worms and leeches are found alike on land and in fresh as well as in salt water. Some worms construct either earthy or stony tubes, in which they live.

The *intestinal worms* that live in the intestines of the greater animals are generally white. Mankind is not exempt from their attacks. The most frequently met with is the *Ascaris lumbricoides*, so called on account of its resemblance to the earth-worm, color, however, excepted. The *tænia*, sometimes called *tape-worm*, is by no means rare either. It looks like a narrow tape divided into rings or segments (Fig. 194), and is sometimes about 20 yards long. At the pointed end of the worm one can perceive, with the aid of a magnifying-glass, a very small head A armed with suckers and hooks. Mankind and flesh-eating animals are subject to having the tænia.

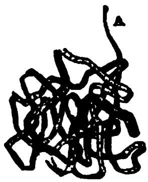

FIG. 194.—Tænia (very much reduced in size). Often called *tape-worm*. A, head. The tænia sometimes is twenty yards long.

The history of these animals is very curious indeed. Each of the ring-shaped divisions of their body is full of eggs, and is sooner or later expelled. This expelled division dries up; the eggs it contained are liberated and lie scattered about. If subsequently a grazing animal happens to pass by and swallows, along with the grass it eats, some of those eggs, they forthwith begin a new evolution. No sooner does the egg reach the animal's stomach than it is hatched, giving birth to a tiny creature that manages to pass through the wall of *the intestine*, and chooses an abode in some part of *the body;*

How do leeches fix themselves to the skin? What is the common color of intestinal worms? What is the scientific name of the worm called *tape-worm?* What does the *tænia* resemble? What length may it reach? By the help of a magnifying-glass what can be seen at the pointed end of the worm? What becomes of its segments? And when cast out, what becomes of them? What becomes of one of these eggs when in the body of a sheep?

once housed there, a sort of ball grows out on the extremity of its body, and, swelling out, all but hides its head. This head is exactly similar to that of the tænia. It is these balls, when developed under the skin of a pig, that occasion a well-known sickness called pigs' measles. The little animal will there and thus remain for any length of time; but were a dog, or even a man, to eat raw or insufficiently cooked (although smoked and salted) pork containing one or more of these globular creatures, the little ball would be digested in his stomach, only the head remaining. In a very short time, however, a segment would add its length to the head, then another and another, and the dog or the poor man would be said to have the tænia.

This is certainly a very complicated way of living, and the history of the tænia should show you *how very essential it is to be careful to eat only wholesome pork, and for further security to have it perfectly cooked, for ordinary curing has not much effect on the little parasite.*

FIG. 195. — A piece of trichinized flesh greatly magnified. At B the little worms are seen buried in the substance of the muscle, and at A they are shown liberated.

In all cases it is prudent to eat *well-cooked meat.* Some fifty years ago, an almost invisible worm was discovered which also lives in pig's flesh, and is called the *trichina* (Fig. 195). In Germany it is very common. When trichinized pork, *imperfectly cooked*, has been eaten, the little creatures, which it contains in great numbers, lay eggs in the intestines; when hatched, the young ones disperse all through the body, causing intolerable pain, intense fever, and often death. These parasites can do no harm if the meat containing them has been thoroughly cooked.

SUMMARY.—ANNULATES.

1. The animals comprised in the great group of ANNULATES seem to be formed by a succession of RINGS or segments jointed together.

What malady does their presence cause in pigs? What may happen to a man who eats of this bacon when insufficiently cooked? What conclusions do you draw from this? What else has lately been discovered in the flesh of pigs or swine? What happens if this meat is eaten when insufficiently cooked?

Annulates are divided into *Insects, Spiders, Millepeds, Crustaceans,* and *Worms.*

2. Insects (p. 68).—INSECTS all have *six* feet.

3. Some of them undergo metamorphoses more complicated still than those of the frog.

4. The *butterfly,* for instance, when newly come out of the egg, is a *caterpillar.* After having several times changed its skin, the caterpillar seems to fall asleep, sometimes wraps itself up in a cocoon and becomes a *chrysalis.* From this chrysalis issues in time a winged butterfly. Such a metamorphosis is said to be *complete.*

5. *Flies, beetles, fleas,* and *bees* undergo complete metamorphoses. *Grasshoppers, dragon-flies, gnats,* and *bugs* have *incomplete* metamorphoses.

6. The group of Insects is the most numerous of all those of the animal kingdom: upwards of ONE HUNDRED AND FIFTY THOUSAND species are comprised therein.

7. The *phylloxera* is an insect almost invisible to the naked eye. It lives on the delicate roots of the *vine,* and sucks them till they are exhausted. Notwithstanding the war waged against these insects, over one million acres of vineyards have already been destroyed by them on the Continent of Europe.

8. Spiders (p. 72).—Spiders have eight legs; near the mouth venomous hooks exist, with which they benumb and kill the insects on which they prey. At the extremity of their abdomen is situated a sort of spinning apparatus, from which issues a very fine and silky thread with which they make their web.

9. In the south of Europe and in all warm countries creatures somewhat akin to spiders are found; these creatures are called *scorpions.* Their sting, situated at the tip of their tail, can occasion intense fever.

10. The *itch* is occasioned by a very tiny sort of spider, scarcely visible to the naked eye, which hollows out galleries under the skin, thus giving rise to intolerable itching.

11. Millepeds (p. 73).—The MILLEPEDS, etc., if they have not so many as a thousand feet, have certainly a great many. Their body is composed of rings.

12. Crustaceans (p. 74).—CRUSTACEANS (crayfish, crabs, etc.) are almost all aquatic animals. Their skin is crusty, whence their name.

13. Worms (p. 74).—If a WORM be cut in two, and left in moist earth, in less than a year two complete animals will be found: a head will have grown on one half, a tail on the other.

14. The *tape-worm,* or *tænia,* looks like a long tape with ring-shaped divisions. Mankind and some animals are often afflicted by the tape-worm.

15. The *trichina,* a little worm almost invisible to the naked eye, lives in pigs' flesh. In order to destroy these trichinæ, the pork must be *carefully and completely cooked.*

III.—MOLLUSKS.

49. The MOLLUSKS are, as we have already seen, soft, fleshy animals in which no trace of ring-shaped divisions exists, and which in many cases have their bodies enclosed in stony shells.

50. Gasteropods.—Those mollusks having a head and a long creeping foot are called *belly-footed*, or *gasteropodous* animals.

The shell of a *snail* (Fig. 196) is a spirally-coiled tube which widens out as it nears the mouth; the body of the snail penetrates into the farthest extremity of its shell.

Look at this snail; it is quite at ease; it stretches itself out and pushes forth its head; it also possesses four horns or tentacles, two of which, A, bear minute eyes, and lastly a

FIG. 196.—Snails. A, horns terminated by small eyes.

FIG. 197. —Slugs.

thick fleshy foot, on which it travels slowly along. If you but touch the creature all this will instantaneously be withdrawn and hidden in the shell.

Slugs (Fig. 197) have, like their cousins the snails, a head, four horns, and a fleshy foot, but no shell to cover their body. In some cases, however, a rudimentary shell does exist, but it is hidden under the skin of the back. The snails and slugs are land-animals. Other gasteropods live in fresh water; but the marine species are by far the most numerous, and present a great variety of forms.

51. Acephala (a name which means *headless*).

The Acephala, *oysters* (Fig. 198), *mussels*, *clams*, etc., have double shells; they are provided with an upper and an under part, called *valves*, whence the name of *bivalves* given to them. These animals have no head, and are aquatic.

To what kind of animals do we give the name of Mollusks? Give some examples.

Oysters are marine animals, that live in large colonies called *beds:* they are fixed on the rocks, and *cannot move out of their place;* mussels and clams, on the contrary, can move about at will. Some live in the sea, and some in fresh water, but they are of different species.

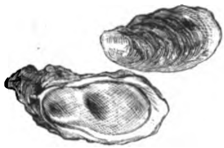

FIG. 198.—Oysters.

The interior lining of the shells of bivalves is utilized under the name of *mother of pearl;* it is often very beautiful, and many pretty things are made of it.

When foreign bodies happen to be introduced between the animal and its shell, a series of shelly caps are formed around them; upon the capture of the animal these are removed, and constitute what are called *pearls*, which are eagerly sought for, and sometimes are of great value.

52. Cephalopods.—There exist in the seas, all over the world, mollusks that generally have no outward shell: they are the *octopus* (Fig. 199), *cuttlefish*, *calamary*, etc. The *nautilus*, whose pretty shells are often brought home by sailors from the Indian seas, is a cephalopod, rather different from those I have just mentioned. They are strange and hideous creatures, with a large head, two great eyes, and a strong, horny beak. Their mouth is surrounded by eight or ten long arms covered with suckers, somewhat like those of the leech, by means of which they lay vigorous hold of whatever comes within their reach. When irritated, some of them emit a black liquid which darkens the water around them, thereby enabling them to escape: this black substance is used for artistic purposes, and is called *sepia.*

FIG. 199.—Octopus.

These animals often grow to an enormous size, and become dangerous even to man. Some have been known to

Where is mother of pearl found? How are pearls formed? What are known under the name of Cephalopods?

measure ten yards or more in length, and their arms were almost as long as the rest of their body. Men in fishing-boats have sometimes been attacked by these marine monsters, which are frequently called *devil-fish.*

All these creatures are so fashioned that their feet surround the mouth, and they are therefore said to be *head-footed* animals, or *cephalopods.*

IV.—RADIATES.

53. The animals comprised under the name of RADIATES or ZOOPHYTES (plant-animals) are of very diversified shape. Almost all of them live in salt water. The best-known and most common among them are the *star-fish* (Fig. 200), the

FIG. 200.—Star-fish.

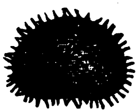

FIG. 201.—Echinus, or Sea-Urchin.

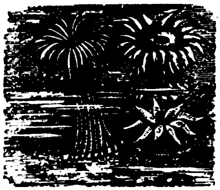

FIG. 202.—Sea-Anemones.

echinus (Fig. 201), or *sea-urchin,* the *sea-anemone* (Fig. 202), the *medusa* (Fig. 203), and the *polypus.* The body of the star-fish is more or less covered with short *spines,* such as are found to a greater degree in the allied *sea-urchin* (Fig. 201). The *sea-anemones* (Fig. 202) are widely different in organization: their bodies are quite soft and flabby, and they have no such spines. They are mostly of fair size and live singly; but some are very small and form great colonies, which are united together by a tough coating; such, for example, are the "dead men's fingers" of the French coast. The coatings of others, called *polypi,* form enormous stony masses called *corals* (Fig. 204), and in the southern seas whole islands of this substance are to be found (Fig. 205).

Which are the best-known radiates?

The *jelly-fishes*, or *medusæ* (Fig. 203), somewhat resemble the anemones in their structure; they are free swimmers, however.

Fig. 203.—Medusa.

Fig. 204.—Agglomeration of Polypi.

We must not omit to mention the *Sponges*. Here is a sponge prepared for use. It has certainly but little likeness

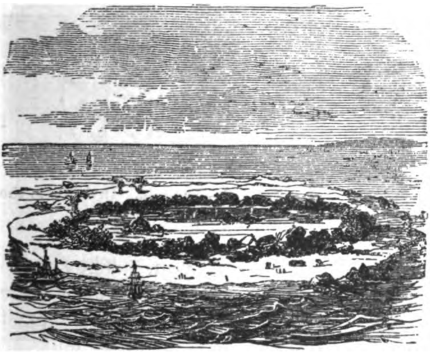

Fig. 205.—Coral Island.

Fig. 206.—Sponge. The sponge used in commerce is only the skeleton of the animal.

to an animal. Yet it was one. Only, when it was a living being, all those solid though elastic parts were enveloped in a living substance (Fig. 206). *What you see here is, in fact, but the skeleton of the sponge.*

What is a sponge? When the sponge was alive, what did it contain more than we generally see in a sponge prepared for use? What, then, is the sponge that is used in commerce?

54. Infusoria.—I will now tell you something about some marvellous creatures most frequently found in decaying animal and vegetable matter. The majority of them are known as *Infusoria*, but there are others, also, which are wonderfully small, yet of no little importance. Look attentively at this glass of water in which I have steeped some bits of old hay. Hold it up between you and the light so as to see very distinctly all it contains. You perceive little mites of things moving in the water (Fig. 207). The magnifying-glass will allow you to distinguish them more easily; but a microscope would be necessary to see them distinctly. Well, these almost imperceptible specks *are little animals that live there in myriads;* there are in the glass tiny creatures of all sorts of shapes. Some are so very small that only the highest magnifying powers can disclose their presence; thousands exist in a drop of water. But where have all these

Fig. 207.—Infusoria (invisible to the naked eye) contained in a drop of stagnant water.

Fig. 208.—Bacteria. Invisible to the naked eye.

tiny beings come from? That puzzles you. They have come from the hay. And how were they there? They were there *dried up, or under the form of eggs.* There exist creatures akin to these in the almost imperceptible moss on the house-tops: quite dried up during the summer-time, if examined with the microscope they look like little grains of green sand. But if a drop of water fall upon them they unroll their folds, and immediately set out to seek their living. When the water has disappeared or evaporated they

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What is to be seen in a drop of water in which some blades of old hay have been infused? Whence come these infusoria? In what condition were they previously? Where are others to be found? Under what influence do they unroll themselves? What becomes of them if the water evaporates?

become inert as before, waiting for another shower. These are very curious creatures, are they not? And they show you that the most interesting and curious creatures are not always the largest. We shall find a new proof of this when we come to study microscopic vegetation.

SUMMARY.—MOLLUSKS AND RADIATES.

1. Mollusks (p 78).—The MOLLUSCAN group comprises snails, slugs, oysters, mussels, cuttle-fish, and their allies.

2. *Mother of pearl* is obtained from the inner layer of the shell of various mollusks.

3. In some oysters, isolated bits of mother of pearl are formed; they take the shape of tiny and beautiful balls: these are *pearls*.

4. Under the title of *Radiates* a great series of groups is sometimes classed, owing to the fact that their bodies are produced into a series of *rays around a central mouth*. Chief among them are the *sea-stars*, the *sea-anemones*, the *jelly-fishes*, and the *polypi*. Whole islands are sometimes formed by the agglomerations of these little creatures.

5. The SPONGES we use are a sort of skeleton formerly enveloped in a living substance.

6. With a microscope one can distinguish in a drop of water in which some old hay has been steeped thousands of tiny animals of infinitely varied shapes. These are INFUSORIA.

7. They existed in a dried state in the hay; in the water they become active and move about.

SUBJECTS FOR COMPOSITION.

1st Composition (pp. 7–14).—Differences between animals, plants, and minerals. Vertebrates and invertebrates. The four great divisions of the animal kingdom.

2d Composition (pp. 15, 16).—What characterizes vertebrates? Warm-blooded and cold-blooded animals. Characters of Mammalia, of Reptiles, of Amphibians, of Fishes.

3d Composition (p. 17).—Aerial animals, aquatic animals. Amphibians.

4th Composition (p. 22).—What shows that a bat is not a bird?

5th Composition (pp. 25, 26).—The paw of the cat. Its teeth. Animals of the cat kind.

6th Composition. (p. 33).—What is *ruminating*, or chewing the cud? The principal ruminants. Services rendered by some of them.

7th Composition (p. 42).—What shows that a whale is not a fish?

8th Composition (p. 45).—General characters of birds. What is there in an egg? How are eggs hatched? Artificial incubation.

9th Composition (pp. 56–58).—What characterizes reptiles? The three groups of reptiles. What happens to lizards that have lost their tails?

10th Composition (pp. 58–60).—Venomous serpents. Tell what you know of the venomous serpents that inhabit our country. Where is the poison formed? Mention serpents whose venom is almost immediately mortal. Non-venomous serpents. How can these be dangerous? Are our snakes dangerous?

11th Composition (p. 61).—Metamorphoses of the frog. By what organs does the tadpole breathe? By what organs does the frog breathe? The venom of frogs and toads. Services rendered by toads.

12th Composition (p. 64).—The various forms of fishes. Give examples. Of what use are the gills?

13th Composition (p. 68).—What is the origin of the word *annulate?* Principal divisions. Different kinds of mandibles met with among insects. The number of legs they possess.

14th Composition (p. 72).—How many legs has a spider? How do spiders kill flies? The spider-like creature that occasions *itch.*

15th Composition (p. 74).—What happens to a worm that has been cut in two? The development of tænia, or tape-worm. The trichina of the pig.

16th Composition (p. 82).—What is to be seen in a drop of marsh water?

PARTS II. AND III.

PLANTS, STONES, AND ROCKS.

PREFACE.

Before the English translation of the "First Steps in Scientific Knowledge" appeared, five hundred thousand copies of the original had been sold in France within three years. Immediately after the appearance of the first English edition a second was called for, and the American publishers feel confident that the success of the American edition will not be less than that of the foreign.

The American editor has made in the excellent translation of Madame Bert only such changes and additions as were necessary to Americanize the book, and adapt it to the requirements of public and private schools as well as to home instruction in this country.

In the Botany several American species have been substituted for others not so well known here, and the classification has been made to conform with that usually adopted in the United States.

In the same manner geological reference has been transferred from Europe to North America.

TABLE OF CONTENTS.

PART II.—PLANTS.

PART III.—STONES AND SOILS.

II.—PLANTS.

I.—Structure of our Trees.

1. Diversity in the Shape and Size of Plants.—You have all noticed, I am sure, that the different members of the VEGETABLE kingdom, or PLANTS, as they are called, vary greatly in form and size. An oak, a rose-bush, a blade of

FIG. 1.—Tree.

FIG. 2.—Shrub.

FIG. 3.—Herbs.

grass, are all three of very different dimensions. To express this we say, there are *trees* (Fig. 1), *shrubs* (Fig. 2), and *herbs* (Fig. 3).

FIG. 4. Mushroom.

All these plants are clad in green, and we shall hereafter see that this coloring is of very great importance. You must know, however, *that there are some plants that are not green: mushrooms* (Fig. 4), for instance, are red, or brown, or white; the

yellowish or brownish gray spots to be seen on the trunks of trees or on walls are nothing else than the tiny plants called *lichens*. There are also innumerable plants which are clearly seen only under our microscopes.

2. The Different Parts of a Plant.—But let us leave for the time being these exceptional plants, and study carefully a common tree.

See here, in a waste corner of the garden, is a young pear-tree that has sprung up of itself, as gardeners say. I shall

Fig. 5.—Wild pear-tree. Roots, A, *b,b,b,b*; C, trunk; D, primary branches; E, secondary branches; F, branch of the third order.

Fig. 6.—Each leaf bears a *bud* A at *its axilla*. This bud will become a *branch*. Certain branches B terminate in a *bud*, which will become a flower, and afterwards the fruit.

pull it up, so that we may examine it together. All of you know the different parts of a tree: 1, the ROOT A (Fig. 5), which is hidden under ground, and whose branchings are called the lateral roots, *b, b, b, b;* 2, the STEM or *trunk* C, that rises up almost vertically; 3, the BRANCHES, divided into

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What are the different parts of a common tree?

primary branches D, starting directly from the stem, *secondary branches* E, taking origin from the preceding ones, then branches of the *third order* F, that spring in their turn from the *secondary* branches, and so on; 4, the LEAVES.

Let us now examine certain parts closely. Above the stalk of each leaf, just in the angle A (Fig. 6), it forms with the stem, or with the branch on which it grows, a small BUD. *This bud will grow and form a new branch. All the branches spring thus from what is called the* AXILLA *of a leaf, and each leaf bears a bud at its axilla.*

You may observe that there are some branches B, usually shorter than others, which, *instead of growing longer*, remain short and end in a flower BUD. These buds will become FLOWERS, and these flowers will pass away and give place to FRUIT, pears in the present case.

3. The Stem.—Let us first take the TRUNK (Fig. 7), and cut it across. It is composed, as you can see, of three distinct parts. In the centre is the PITH A, white and soft; then comes the WOOD B, which is hard; lastly all around you can recognize the bark C, which is green and tender, and which you can pull off in strips.

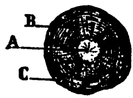

FIG. 7. — The trunk.
A, the pith.
B, the wood.
C, the bark.

This tree we are now examining is a very young one, it sprang up but last year from the roots of an old pear-tree that perished by the severe cold of the winter; its stem is quite slender. But I have here beside me a piece of the trunk of the old tree (Fig. 8), which I kept as a curiosity on account of its great age. We will compare it with the young stem.

The first thing to notice is that the old trunk is much larger than the young stem, the diameter of the former measuring about forty inches. Strange to say, the *area occupied by pith in the old trunk is no greater than in the young stem.* This astonishes you, I have no doubt, yet it is always so. In no case whatever does *the pith grow bigger as the tree grows*

What is to be seen at the *axilla* of each leaf? What will arise from the bud? Where do all the branches spring from? Have all the branches the same characters? What becomes of these buds? If the trunk be cut across, what three parts are discernible? What is to be remarked about the pith of an old tree?

older. As for the BARK C, it is no longer green and smooth, but has become gray, rugged, and much thicker. The principal difference, however, is in the bulk of the *wood* B, for it alone makes up almost the whole stem, or trunk, as people call it when speaking about the stem of an old tree.

FIG. 8.—Transverse section of the stem of an old pear-tree. A, pith, which does not increase with age; B, wood with circles fitting into one another, each circle marking a year; C, the bark.

Here is a slice of the old trunk which I have had polished. *Do you see those* RINGS *all fitting exactly into one another?* Will you count them?—"There are about 65."—Why do you say about 65?—"Because *the rings, very easily counted near the pith, are so closely pressed together near the bark that I can scarcely distinguish them.* How does this happen?"

Follow my explanation, and you will easily understand why this happens. *Each of these circles marks* ONE period of growth of the wood, and generally one YEAR *of the life of the tree* (this one, then, would be about sixty-five years of age). Every year the tree grows thicker; you understand, of course, that this growth can only take place outwardly, for were the new layer of wood to be formed inside the tree, near the pith, all the old wood, being hard, would be split open and torn apart. The new wood grows between the old wood and the bark. Each of the circles you see corresponds to a yearly layer of wood.

Now, when the tree was young it grew much faster than in its old age; just as children do; for you grew much more rapidly between four and five, than you will grow from fourteen to fifteen. This is why the *thickness of the rings is less as they go farther from the centre* of the stem; that is to say, as they are of more recent formation.

Are any other distinctions made between the different parts

Which part of the trunk of a tree develops the most with age? What is to be seen on attentively examining a slice of wood cut across the trunk? Can these rings be easily counted? What does each of these circles indicate?

of the wood itself? Can you tell me?—"Yes, there is the SAP-WOOD A (Fig. 9), which is soft, and the HEART B, which is hard, and is found under or within the sap-wood."—Quite right; *the heart is harder because it is older, and a greater quantity of solid matter has been deposited there, during a longer period of time,* consequently it will give more heat and leave a greater quantity of cinders, if used as fuel.

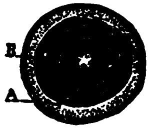

FIG. 9.—A, sap-wood; B, the heart.

4. The Root.—So much for the *structure* of the stem. That of the ROOT is similar. There is so little difference between the roots and the stem that sometimes, as is the case with the lime-tree, the acacia, and the chestnut-tree, for instance, when a part of the root is laid bare for any considerable length of time, it becomes quite like the stem so far as appearance is concerned, and may even give rise to branches.

5. Branches.—The way in which the branches stand related to the stems is exceedingly varied. Look at the *fir-*

FIG. 10.—Horizontal branches of the fir-tree.

FIG. 11.—Plum-tree, branches out in all directions.

tree (Fig. 10). It gives off at regular intervals horizontally directed branches; on the contrary, this *plum-tree* (Fig. 11)

What else may be observed of the different parts of the wood?

branches out in all directions, so that one can scarce follow the main stem. Still, whatever aspect the tree may have, *the stem is always thicker at the lower parts than at the higher.* It tapers gradually, and ends almost in a point. This is the case with all the trees of our country, except a few species of palm found in the South.

6. Leaves.—Let us now consider the LEAVES. Those of our pear-tree have stalks A (Fig. 12), or, to use a more scientific

FIG. 12.—Leaves of the pear-tree.
A, petiole.
B, blade, or lamina.

FIG. 13.—Wild Geranium leaf, blade divided.

FIG. 14.—Buttercup leaf, blade completely divided.

FIG. 15.—Acacia leaf, blade with complicated divisions. *a*, *b*, *c*, lobes of the leaf or leaflets; B, bud; P, petiole of the leaf.

What general observation may be made regarding the trunks of trees in our own country?

expression, each has a PETIOLE. The petiole supports an outspread green part, which is the leaf properly so called,—the *blade*, or *lamina*. This blade is the most important part of the leaf, and many plants have leaves without stalks. The leaf of the pear-tree has a *simple* blade, while that of the wild geranium (Fig. 13) is *divided* into several parts. The divisions are *complete* in this buttercup leaf (Fig. 14), and *extremely complicated* in the leaf of the acacia (Fig. 15). I think I heard some one whisper that each of these green lobes *a*, *b*, *c* is by itself a whole leaf. I say he is mistaken. Can any one tell which of us is right, and why? Nobody? Do you not remember I already told you that *at the axil of each leaf a little bud was to be found?* and you see in this case one only exists, B; and it is situated at the axil of the whole leaf. Besides, if those big petioles were small branches, they would not fall in autumn; and you know that they fall as the leaves.

7. The Flowers.—And now to the FLOWERS. The first things that meet our eye in the pear blossom (Fig. 16) are

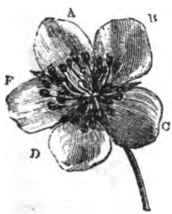

FIG. 16.—A, B, C, D, E, petals. These taken together form the *corolla*.

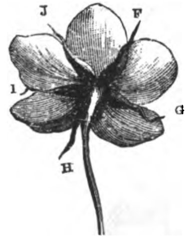

FIG. 17.—F, G, H, I, J, sepals. The aggregate of these sepals forms the *calyx*.

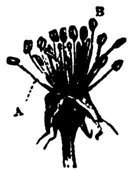

FIG. 18.—A, *stamens*; B, yellow anthers bearing the *pollen*.

those five little outspread white leaves A, B, C, D, E. They are called PETALS. If we now look at the under side of the flower (Fig. 17), we shall see five other leaves F, G, H, I, J, much smaller than the first, and that have remained green;

What is the scientific name for the stem of a leaf? What name is given to the green part? Is the blade always of the same shape? What proves that the lobes in the leaves of the acacia-tree are not leaves? Give another proof. What name is given to the five little white leaves which form the blossom of the pear-tree?

these are called SEPALS. In the centre of the flower (Fig. 18) there are a number of little things like bristles, A, each finished off by a tiny yellow ball, B: these are the *stamens;* they owe their yellow color to a sort of very fine dust, that botanists call POLLEN. You are all aware of the existence of this yellow dust, and that it can easily be shaken or blown from the stamens which bear it.

FIG. 19.
A, ovary becomes the *fruit;* B, styles; A and B taken together form the pistil; C, ovules (or white specks), which become *pips*, or *seeds*.

We will now pluck off the sepals, petals, and stamens: I must not, however, omit to mention that the petals all together form what is called the COROLLA (Fig. 16), while in the same manner the sepals form the CALYX (Fig. 17). We have reduced our pear blossom to a little ball, A (Fig. 19), surmounted by five minute stalks, B. This ball is called the OVARY, or seed-vessel, the little stalks are the STYLES, and the ovary and the styles, taken as a whole, form what is called the PISTIL.

FIG. 20.—A, remains of the disappeared styles.

FIG. 21.—A, pips, or seeds.

8. Fruit.—A very little thing, indeed, is the ovary; if spared it will, however, grow big when the calyx, the corolla,

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What name is given to the five little green leaves that are found under the flower? What name is given to the little bristles in the centre of the flower? How do the stamens terminate? To what is the yellow color due? What name is given to the *petals?* To the *sepals?* What remains when the sepals, petals, and stamens have been taken away? What name is given to this little ball? To the stalks? To the ovary and styles together?

and the stamens have fallen away. It will swell out and become filled with juice, at first sour but afterwards sweet; it will, in short, become a *pear:* the FRUIT. You can easily recognize the ovary after its transformation into a pear, for on the summit A of the fruit (Fig. 20) you still find traces of the parts that have disappeared; they have made a little hollow right opposite the stalk.

In this fruit, you know, there are *seeds* A (Fig. 21), loosely hung in small cells. If we cut across the ovary of our pear blossom (Fig. 19), we shall see in it very small white specks, C. These specks, which we can pick out with a pin, are called OVULES; that is to say, *little eggs.* These tiny things, in the course of time, will become the *seeds* (Fig. 21).

So a CALYX, a COROLLA, and STAMENS *destined to disappear, an* OVARY *which is to become a* FRUIT, and OVULES *that are to become* SEEDS, *such is the composition of a* PEAR *blossom.*

9. Imperfect Flowers.—A flower such as that of the pear-tree is said to be *complete.* There are also *incomplete ones.* In some the calyx is wanting, in others the corolla, sometimes even both, but this is of no great importance.

I see this astonishes you, and that in your opinion the most important parts of the flower are the beautiful petals so often decked in gay and brilliant colors. But this is not the case. *The really important parts of the flower are the* STAMENS *and the* OVARY; I should even say the GRAINS OF POLLEN and the OVULES.

What proves this is that many flowers have neither calyx nor corolla. The flower of the hazel-nut, for example, has neither, and yet the hazel-tree (Fig. 22) bears fruit, as you well know, and that is the principal end of its existence. Another proof is that you may pluck away the petals and sepals of a perfect flower, and by no means hinder the growth of the fruit, provided the stamens and the pistil remain uninjured. *But if you pick off the stamens the ovary will not develop*, or, as horticulturists say, the fruit will not *knot.*

What becomes of that little ball? What is to be found in the fruit? What will these tiny specks become in the course of time? What then becomes of each part of the pear blossom? Which is the most important part of the flower? What happens if you destroy the stamens of a flower?

FIG. 22.—Flowers of the Hazel-nut. They have neither calyx nor corolla.

FIG. 23.—Flower of the Maize, or Indian corn. A, flowers with stamens; B, flowers with pistils.

This is not all: there are also flowers that do not possess both *stamens* and *pistils;* some bear stamens, while others bear pistils. *Such flowers, if kept too far from one another, remain barren;* that is to say, produce *no fruit.* Sometimes both kinds of flowers grow upon the *same plant*, as is the case with the melon, the birch, the walnut-tree, the maize, or Indian corn (Fig. 23). Sometimes each grows *upon a different plant;* this is the case with hops, hemp, willows, maples, etc. If these plants are not near enough to each

FIG. 24.—All the Weeping Willows of America and Europe have flowers with pistils (those with stamens are in Asia).

Do all flowers possess both stamens and pistils? What happens if these flowers are kept far apart from one another? Where are the two kinds of flowers found in the melon, birch, walnut-tree, and maize? In hops, hemp, willow, and maple?

other they will never bear fruit. See there, on the water's edge, that beautiful weeping willow (Fig. 24); it is a native of Asia; and, as only one kind has been brought to this country, the one bearing pistils, nobody in our part of the world ever saw any of its seed, and all the trees of the kind that decorate our gardens have come from *slips*, and bear flowers with ovaries that remain unfruitful.

10. Seed.—We will now return to our pear blossom, or rather to its fruit. It contains *pips*, or *seeds*, which if put in the ground *will produce pear-trees similar to the tree that bore them.* Let us examine carefully one of these seeds. We first meet with a *covering*, or *skin*, and within it the seed properly so called. As the seed of the pear-tree is too small to allow us to see its details with sufficient accuracy, we will take a larger one, that of an almond-tree, for instance.

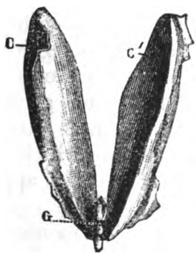

Fig. 25.—The almond is composed of two large fleshy bodies C, C′, called *cotyledons*. G is a plant in miniature.

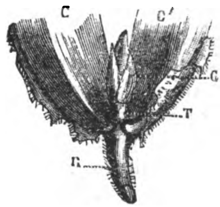

Fig. 26.—C, C′, cotyledons; R, radicle; G, plumule.

The skin once removed, we find two fleshy bodies (C, C′, Fig. 25), which are very savory, and which make up almost the whole bulk of the almond. Botanists have given them the name of *seed-leaves*, or *cotyledons.* I do not like to give you those big, ugly Greek words, but very often it is impossible to avoid them.

What is remarkable about the weeping willow? What becomes of pips and seeds when put into the ground? What may be observed in the seed of a pear? When the skin of an almond is taken away, what remains? What name do botanists give these two fleshy bodies?

See, I have carefully separated the cotyledons. Do you perceive, at the pointed end of the seed, a little body G? Look at it closely, very closely; *it is really a miniature plant.* One can distinguish, without great difficulty, a tiny root R, or *radicle* (Fig. 26), a minute stalk T, and, on the top, a very small bud. And the cotyledons C, C′, of what use are they? They are simply the first two leaves of the plant. Were we to put the little fruit (the almond) in the earth, the radicle R would become the root T, and the plumule G would grow up to form the plant. As for the cotyledons, their history is more complicated, and we will hereafter see what becomes of them when we study *germination.*

II. Structure of Palm-Trees.

11. We have, in a general way, gone over the history of our pear-tree and its fruit. I now wish to examine with you another tree, one altogether different from the foregoing, a *palm-tree.* Unfortunately, none grow in the northern part of this country except in hot-houses. To find one growing we should be obliged to go to some warm climate. In the Southern States, however, is found the palmetto, which is a small kind of palm, and what we shall learn of the palm applies also to the palmetto.

You may ask, But why, then, choose the palm-tree? There are in this country many other trees,—the oak, elm, poplar, etc. Quite true; but *what I have told you concerning the pear-tree is applicable to all those trees, nay, even to all the trees of our country except the palmetto.* All these have a TRUNK *thicker at the base than at the top,*—a *conical* trunk, to use the geometrical expression; all have a BARK, and WOOD harder in the centre, and *rings* fitting into one another, and PITH; their stems all bear BRANCHES or TWIGS, which come from BUDS situated at the axillæ of the LEAVES; all of them also bear *seeds* that have TWO COTYLEDONS.

But a palm-tree is altogether different, and it is for that

What is seen at the pointed end of the seed? What do you perceive there? What are the two cotyledons? What would happen if we were to put the whole fruit in the ground? State the general characteristics of the trees of our country.

reason I find it necessary to tell you about it. Fortunately, I have been able to procure some good engravings that will help you to follow my description.

12. General Aspect.—Observe in the first place the general appearance of the tree (Fig. 27); how different it is from those of our forests. *No branches are to be seen along the trunk*, and only on the top A we find a tuft of *leaves*, long, strong, and stiff. *The trunk* B *itself is from* TOP TO BOTTOM OF EQUAL THICKNESS; it is *cylindrical*, not *conical*. From the top, beneath the leaves, great bunches of flowers hang down.

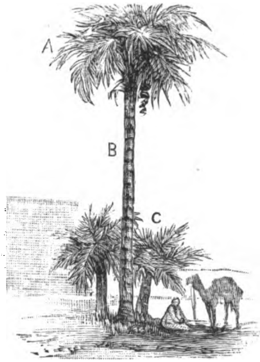

Fig. 27.—Palm-tree. Trunk from top to bottom of the same dimensions (cylindrical).

This palm-tree is, as you may judge by comparing it with the Arab passing on camel-back, about forty-five feet high. It is a tall tree, but close to it is a young one C, not more than nine feet high, although its trunk is

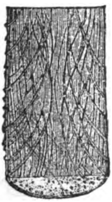

Fig. 28.—Trunk of palm-tree. The scars indicate the place where the leaves have fallen off.

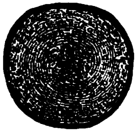

Fig. 29.—Transverse cut of the trunk of a palm-tree. No pith, no circles of wood fitting into one another, no bark.

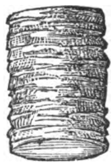

Fig. 30.—Longitudinal cut of the trunk of a palm-tree, showing the hard, black filaments which give strength to the trunk.

What difference exists between the branches of the palm-tree and those of other trees? In the trunks? What other great difference is there between a palm-tree and our trees? What palm grows in the United States, and where?

as thick as that of its elder brother; strange to say, *however tall it may grow, it never will be thicker* than at present. This, then, is another great difference between the palm-tree and our oaks, elms, apple-trees, etc.

Look also at the trunk of the palm-tree (Fig. 28). You see upon it a series of regular scars. They mark *the place of leaves that have fallen off;* only the highest leaves remain. These form the luxuriant tuft which is the sole ornament of palm-trees. These trees have but ONE BUD OR SHOOT, *situated on the top of the tree, and at that point alone the plant grows.* There are no side-shoots, hence no branches.

13. Stem.—Let us now examine this bit of stem cut across (Fig. 29). What a strange texture its parts have! Here we find no pith, no rings of wood fitting into one another, no bark. Instead of the regular arrangement we have been accustomed to see, we have here a *spongy mass, in which are seen an immense number of hard black spots, irregularly arranged.*

What can these black spots be? In order to ascertain this, I have cut the stem of the palm-tree, not across, but lengthwise, through the middle (Fig. 30). This shows us, running through the spongy mass (which more or less resembles the pith of our trees), hard black fibres that appeared as black spots awhile ago in the transverse section we examined. These fibres have a very irregular direction, and seem, at first sight, to wander through the soft mass, which they bind together. If closely looked at, however, it will be seen that they all come from the leaves, run down into the interior of the stem, and thence come back to the surface, where they disappear. *These threads or fibres are nothing else than the wood of the palm-tree, which is made up, as you see, in a very peculiar fashion.* The number of fibres is large enough to give the stem sufficient strength to admit of its being used as timber.

What is the cause of the scars that may be observed on a palm-tree? How many buds are there in the palm-tree? Where is this single bud situated? What is found in the palm-tree instead of the pith and the rings of wood fitting into one another? What direction do the fibres take that we see running through the interior of a palm-tree? What are these fibres?

III. — Dicotyledonous and Monocotyledonous Plants.

14. There are, then, between a palm-tree and a poplar, for instance, wide differences in appearance and in structure. Moreover, while the seed of the poplar and that of other trees of similar construction have, as we have already learned, TWO COTYLEDONS, the seed of the palm-tree and that of all plants of like structure have but ONE COTYLEDON.

It is, then, quite natural to divide the vegetable kingdom into MONOCOTYLEDONOUS plants (from the Greek *monos*, which means *one*) and DICOTYLEDONOUS plants (from the Greek *di*, which means *two*).

In each group there are both trees and shrubs.

IV.—Duration of the Life of Plants.

15. Annual, Biennial, Perennial Plants.—The length of the life of plants is extremely variable.

There are some which shoot up in the spring, grow stems and leaves, give flowers, fruit, and seed, and then perish at the end of the warm season, all in the course of a single year. Such are called *annual* plants.

Others *vegetate* during the first year; that is to say, they bear only leaves; they live through the winter. The second year they flower and bear fruit, then they die. These are *biennial* plants.

Annual and biennial plants have but one *inflorescence*, or *flowering*, and one *fructification*.

Plants are called *perennial* when they flower several times in the course of several years.

In some *the roots alone are perennial*, as in the dahlia. Every year the knotted root, or *tubercle*, shoots forth beautiful soft stalks that bear flowers, and die in the autumn; such is

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What fundamental difference is there between the seed of a palm-tree and that of one of our own trees? To what great division do palm-trees belong? What is to be observed in annual plants? What takes place in biennial plants during the first year? During the second year? In what do annuals and b ennials agree as regards their flowering? Their fructification? What are perennial plants?

also the case with asparagus, hops, etc. These plants have perennial roots and annual stalks.

The *true perennials are* the *trees* and *shrubs*. They grow larger every year; but none of their aerial parts except the leaves die, and year after year new flowers and new fruit cover their young branches. Some kinds of trees live to a great age, and die only as the result of accident. Trees are known that are more than a thousand years old.

V.—Classification of Plants.

16. I will now speak to you about the *classification of plants*. This is perhaps more difficult than that of animals, because plants resemble one another more closely than animals do. Everybody is able to distinguish insects from birds, and, among insects, flies from butterflies; but it is not so easy to draw lines of division in the vegetable kingdom.

Suppose I were to task you with this classification, how would you set to work?—"Why, I should begin by dividing them into trees, shrubs, and herbs."—Well, that idea has occurred to many people; but see how many difficulties rise before you. Pray what limits could you find between the three classes? Where does the group of shrubs end and that of trees begin? and when does a plant merit the name of a shrub instead of being numbered among herbs? Are hazelnuts found on a tree or on a shrub? Is corn a shrub or an herb? The distinctions are not sufficiently definite. What do you say?

"I think I should class plants as annuals, biennials, perennials by roots, and the true perennials, as you did a little while ago."—This is certainly a better plan. But is not meadow-grass very like corn? Yet corn is annual, while meadow-grass is perennial: meadow-grass and corn would, then, come under two different categories. More than that, the oats we cultivate are annuals, while the wild oats that grow along the roadsides are perennials. Here again are two

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Some plants are perennial only in the roots; what takes place regarding these plants? Which are the typical perennials?

yellow *buttercups* I gathered side by side: one is an annual, the other a troublesome perennial weed almost impossible to destroy. You see this system is far from being perfect.

17. Importance of the Characters of Flowers.—After long research, botanists have come to the conclusion that the best divisions are those founded on the structure of the *flowers*, the *fruit*, and the *seeds;* in a word, all that tends to PERPETUATE THE SPECIES of the plant.

This conclusion ought not to surprise you, since you already know that the form and structure of the stems of trees whose seeds have but one cotyledon differ widely from those of trees whose seeds have two cotyledons.

Thus a series of great groups has been formed, bringing together under a common head plants often very different in appearances, but *bearing flowers having great likeness to one another.*

18. The Leguminosæ.—I have no doubt that you all know the locust, the wistaria, the lentil, the clover, the pea, the bean, the kidney-bean, the rattlebox. Some of these plants are simple herbs, others are shrubs, others are trees; there are in the number annuals, biennials, perennials; some creep on the ground, some climb, while others stand firm and erect; some have soft leaves, some prickly ones. But if we examine the flowers, fruit, and seed of all these plants we shall see that they are all formed in the same manner, or very nearly so; so that if we trace the history of any one of these flowers, what we say concerning it will be applicable to each and all of them; for they differ but little except in size and color.

Let us take, for example, a blossom of the common pulse (Fig. 31) that grows on the roadside and displays at this season thousands of bright yellow flowers.

You find at first some difficulty in distinguishing the *sepals* D, which are fastened together, the five points alone being free. Inside is the *corolla*, with its five *petals;* and very unlike one another they are. Here is one, A, much larger than the others, and rising almost erect; beside it are two

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By what characteristics have botanists established a vegetable classification? What aspect do the sepals of the common pulse present? How are the petals arranged?

smaller ones, BB, one on each side; lastly, the two remaining ones, C, are united into something shaped like a boat's keel. The *stamens* E also are peculiarly arranged, as you

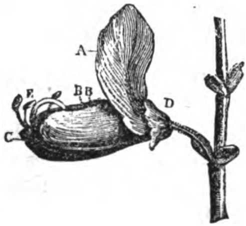

Fig. 31.—Flower of the common pulse, side view. A, B, C, petals; D, calyx; E, stamens.

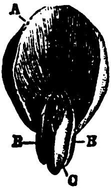

Fig. 32.—The same, front view. A, B, C, petals forming the corolla.

may see. There are ten in all (Fig. 33): nine of them are united together at the base, one only, F (Fig. 34), being free. They thus form a long tube, split open on one side, in

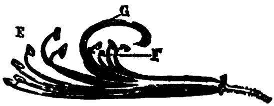

Fig. 33.—The ten stamens of the common pulse.

Fig. 34.—Nine of the stamens are united at the base; one only, F, is free.

which the *ovary* O (Fig. 35) is situated. But the ovary will be much more easily examined when it has become a fruit or a pod.

Fig. 35.—O, ovary of the pulse plant.

And as the fruit, or pod, of the pulse is very like that of the bean, I only have to recall this latter to your memory. Everybody knows what the *pod* of the bean is like: it looks almost as if it were a leaf folded in two, with its edges fastened to-

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How many stamens has the flower of the common pulse, and how are they arranged? Where is the ovary situated?

gether (Fig. 36). Everybody has also seen, inside the pod, its edible seeds, called *beans*. The bean being a large seed, you will easily discern the tiny plant between the two fleshy cotyledons which envelop it, and which will also serve, as we shall afterwards learn, to nourish it when it begins to sprout.

And now, after the pulse and the bean, take the flower of the pea; examine also its pods and its seeds; you will again find in them the same parts similarly arranged.

The flower of the clover, being smaller, is not so easily examined; but with patience and sharp eyes you will be able to convince yourselves that it also is of like structure.

It is quite reasonable, then, to put all these plants together in the same class. So, as I have already told you, all of them come under the general FAMILY name of LEGUMINOSÆ (from the Latin *legumen*, vegetables, or pot-herbs). This name has been chosen because many plants of this family are used for culinary purposes.

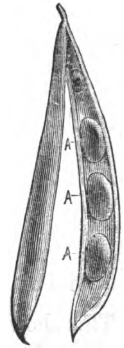

FIG. 36.—Pod of an open bean. A, seed (bean), containing the little plant and the two cotyledons.

19. The Rosaceæ.—Let us once more return to our *pear blossom*, and examine it more closely even than before, or, better still, we will substitute for it this wild rose (Fig. 37), which is of the same family and has a larger flower. You see it has five sepals A united together at the base, and containing first five petals B, then a great number of stamens C; lastly, the ovary D, hidden within the calyx and adhering to it. Well, the flowers of the blackberry and strawberry, and of peach, almond, cherry, and plum trees, etc., are all arranged very much in the same manner. Important differences exist only in the ovary, and, consequently, in the fruit; for we find among these plants which we have just named some that bear *fleshy fruit with pips* (pears, apples), others with *stones* (peaches, cherries, plums), others with but *little flesh*, and with *kernels* (almonds), etc.

What is to be seen in the pod, when the ovary has become a fruit under the form of a pod similar to that of the bean? What is the name given to the group of plants having the same characteristics as pulse? Name some of these plants.

Yet on account of the similarity of their flowers botanists have classed all these plants in the ROSACEÆ family, so called because their flowers have the same structure as that of the rose.

FIG. 37.—Wild Rose. A, calyx; B, corolla; C, stamens; D, ovary.

This shows the importance of the structure of the *flower*. Let us, then, continue to examine some of those that bloom in spring, at the same time as the pear.

FIG. 38.—Yellow Cowslip (Primulaceæ). A, calyx; B, corolla.

20. Primulaceæ.—See, here is the *primrose*, or *cowslip* (Fig. 38), found in abundance in some of our meadows during spring. You see it has five sepals joined together, A, then five petals B, also united at their bases so as to form a pretty long tube. Let us cut open this tube (Fig. 39): within it you will see, adherent to the side of the tube, five stamens C.* At the lower end of this tube is situated an ovary D (Fig. 40), quite isolated, and bearing a long style. This ovary will become a fruit- or seed-case, which when ripe will open at the top just like a box (Fig. 41).

Along with the primrose have been classed the blue and

*** The section of the flower being in two parts, we can show only three stamens in the figure.**

the red pimpernel, the star-flower, the water-violet, etc. All these flowers form the family of the PRIMULACEÆ.

21. The Ranunculaceæ.—Here is a common *buttercup* (Fig. 42). We find five sepals A, quite separate this time; five petals B, also separate; a great many stamens (Fig. 43),

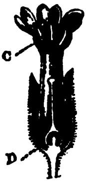

FIG. 39. C, stamens; D, ovary.

FIG. 40. D, ovary.

FIG. 41. Fruit of the Pimpernel.

and in the centre a considerable number of small ovaries (Fig. 44), which will hereafter become so many seed-boxes, each containing one seed. The buttercup is the type of the family of the RANUNCULACEÆ (from the Latin *rana*, a frog, because found in meadows where frogs are numerous), to which belong also the clematis, anemone, pæony, hellebore, etc.

FIG. 42. — Buttercup (Ranunculaceæ). A, five separate sepals; B, five separate petals.

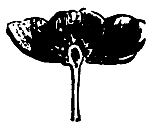

FIG. 43. Open buttercup.

FIG. 44.—Ovary of buttercup.

22. The Liliaceæ.—Here is a stalk of the *lily of the valley* (Fig. 45), a flower very different from any we have yet seen. It has but one floral envelop A, which looks like a little round bell. This bell has on its edge six notches, which show us that there are here six petals blended into one, except at the very tips. At the bottom of the bell (Fig. 46) are to be seen six stamens and an ovary, which will become a small, fleshy fruit, properly called a *berry*. The lily of the

valley is akin to Solomon's seal, asparagus, onion, garlic, etc.; it belongs to the family of the LILIACEÆ.

23. The Salicaceæ.—The flower I now show you is as quiet and dull-looking as possible (Fig. 48): no brilliant colors has it to attract the eye. It is the flower of the *willow*, the one which bears stamens; for, as I have already told you, in this plant both kinds of flowers (flowers with pistils and flowers with stamens) do not grow from the same root, but upon two different plants. This willow flower has neither calyx nor corolla, but merely two stamens A (Fig. 49), situated at the base of a sort of little leaf-like scale called a *bract*, B. The willow, the poplar, and the aspen belong to the family of the SALICACEÆ.

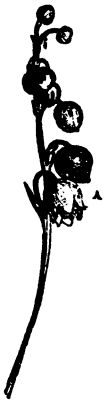

FIG. 45.—Lily of the Valley (Liliaceæ).

FIG. 46. Bell showing the stamens and ovary of the lily of the valley.

FIG. 47.—Ovary of the lily of the valley.

24. The Compositæ.—I shall finish this lesson with the examination of one of those little daisies (Fig. 52) whose white

FIG. 48.—Flower and stamens of the willow (Salicaceæ).

FIG. 49. A, stamens of the willow; B, bract.

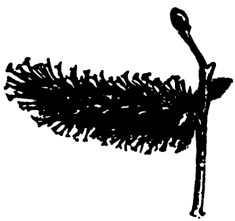

FIG. 50.—Flower and pistil of the willow.

FIG. 51. Ovary of the willow.

flowers adorn our meadows and roadsides, and which, as soon

as evening falls, seem to sleep snugly wrapped up in their pretty frills all through the dark night, until the warm sunshine awakens them at morn and invites them to unfold their wrappings and enjoy the bright and genial rays. I will trust you with this examination; but let me warn you that, notwithstanding the modest look of the flower, it will

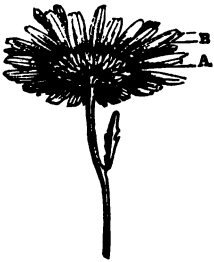

FIG. 52.—A daisy as seen from beneath.

FIG. 53.—A daisy as seen from above (Compositæ).

A, crown of small leaves; B, half florets.

give you no little trouble. In the first place, how many SEPALS A do you find?—"More than twenty."—Indeed! and how many petals?—"If all those white blades B (Fig. 53) are petals, there are a great many."—Well, count them, pray, and the stamens and the pistils also.—"Ah! sir, I am altogether bewildered; the little yellow things (Fig. 54) I took to be stamens are certainly something else, for I see with your magnifying-glass that each has five notches: they look more like tiny flowers than anything else I know."—And flowers they are. Each of those minute flowers has five petals joined together, forming a tube (Fig. 55); inside are five stamens with a pistil which contains an ovule, or tiny seed. All this can be seen with a good magnifying-glass. Those small flowers are called *florets*.

FIG. 54.—Section of a daisy. C, florets.

The white blades B (Fig 56), which you counted at first as

petals, are also flowers: each blade is composed of five petals blended together in a lamel B at the upper end, and forming a tube D at the lower. They are called *half florets*.

Lastly, your so-called sepals are merely leaf-like organs called *bracts*, wreathed around the bunch of flowers, just like the leaves sometimes put around a bouquet.

The family to which our daisy belongs well merits, as you see, the name of COMPOSITÆ. This is a very numerous and extremely varied family. To it belong the thoroughwort, the aster, the golden-rod, the sunflower, and many others.

FIG. 55.—Floret of the daisy.

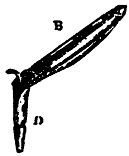

FIG. 56.—Half florets of the daisy.

25. Principal Families.—We have but few flowers at our disposal at the present time, early spring giving more green leaves than flowers. But as others come into bloom we shall find occasion to examine the principal ones among them, and learn their structure, their families, and their names.

FIG. 57.—Papaveraceæ (Corn-Poppy).

FIG. 58.—Cruciferæ (Colza).

FIG. 59.—Caryophyllaceæ.

I shall now indicate briefly how we should classify the most important plants, those you know best or have heard most about.

We shall begin with the DICOTYLEDONS. Here are the *Ranunculaceæ*, with which you are already acquainted. Then

FIG. 60.—Malvaceæ (Mallow).

FIG. 61.—Leguminosæ (Cultivated Pea).

FIG. 62.—Cucurbitaceæ (Melon).

come the *Papaveraceæ* (Fig. 57), among which we find the *Poppy* (in Latin *Papaver*), the corn-poppy, and their allies.

The *Cruciferæ* (Fig. 58) (a word which signifies *cross-*

FIG. 63.—Umbelliferæ (Chervil).

FIG. 64.—Rubiaceæ (Madder).

bearer), thus named because their four petals are arranged in the form of a cross. This is a numerous family, which com-

prises the wallflower, water-cress, stock, mustard-plant, cabbage, colza, radish, horseradish, etc.

The *Caryophyllaceæ* (Fig. 59), to which belong the carnation, pinks, soapwort, catchfly, common chickweed, flax, and many others.

The *Malvaceæ* (Fig. 60), or *Mallow family*, to which belong the mallow, marshmallow, etc.

The *Leguminosæ* (Fig. 61), with which you have already made acquaintance.

The *Rosaceæ* you also know.

FIG. 65.—Compositæ (1st type, Daisy).

FIG. 66.—Compositæ 2d type, Artichoke).

FIG. 67.—Compositæ (3d type, Chiccory).

The *Cucurbitaceæ* (Fig. 62), comprising the cantaloupe, watermelon, cucumber, pumpkin, squash, etc.

The *Umbelliferæ* (Fig. 63), whose flowers are borne upon little stalks, all aggregated at the tip of the principal stem, and thence branching out, forming what is called an *umbel.* Among these are classed parsley, angelica, parsnip, carrot, chervil, the poisonous hemlock, etc.

The *Rubiaceæ*, or *Madder family* (Fig. 64), comprising the coffee-plant, cinchona, ipecacuanha, etc., besides madder, whose roots furnish a fine red dye, whence the name of the family, *Rubiaceæ* (from *ruber*, the Latin for red). The members of this family are natives of tropical countries.

The *Compositæ* (Figs. 65, 66, 67), in which there are three types. Some, like the daisy, have a wreath of half florets around a disk of florets: such are the marigold, sunflower, Jerusalem artichoke, groundsel, chamomile. Others have only florets: the thistles are of this description, also burdock and artichoke. Others have only half florets, like chiccory, lettuce, salsify, dandelion.

The *Boraginaceæ* (Fig. 68), comprising heliotrope and forget-me-not.

The *Solanaceæ* (Fig. 69), among which are placed the potato, bittersweet, belladonna, henbane, tobacco, thorn-apple.

FIG. 68.—Boraginaceæ (Borage).

FIG. 69.—Solanaceæ (Potato).

FIG. 70.—Scrophulariaceæ (Foxglove).

The *Scrophulariaceæ* (Fig. 70), the best known of which are mullein, digitalis, or foxglove, veronica, or speedwell, snap-dragon, etc.

The *Labiatæ* (Fig. 71), or *Mint tribe*, which have an almost square stem, and comprise mint, sage, thyme, marjoram, balm, rosemary, lavender, etc.

The *Euphorbiaceæ* (Fig. 72), comprising the euphorbia, or spurge, croton, boxwood, stillingia, dog's mercury, etc.

The *Urticaceæ*, or *Nettle tribe*, including the hemp, hop, fig, nettle, mulberry, elm, etc.

The *Cupuliferæ*, comprising the oak, chestnut, walnut, hazel, birch, beech, etc.

The *Betulaceæ*, including the various kinds of birch and alder.

The *Coniferæ* (Fig. 73) (or cone-bearers: so called on account of their fruit): the greater number of these do not lose their leaves all at once in the autumn, and therefore merit the name of *evergreens*. The principal members of this tribe are the pine, fir, larch, cedar, juniper, yew, and cypress.

We come now to MONOCOTYLEDONS.

FIG. 71.—Labiatæ (Thyme).

FIG. 72.—Euphorbiaceæ (Euphorbia).

FIG. 73.—Coniferæ (Pine).

When speaking of the *Liliaceæ* (p. 27), I showed you that its flower bore six notches, there being a union of *six* floral leaves to form it, instead of *five* as with the majority of other plants which we had considered up to that time. In fact, in most *dicotyledons* the parts of the flower (sepals, petals, and stamens) are in sets of *five* or multiples of *five*, whereas in most *monocotyledons* they are in sets of *three* or multiples of *three*.

The *Liliaceæ* (Fig. 74), or *Lily tribe*, are plants with bulbous roots, among which are the tulip, garlic, hyacinth, onion, shallot, and asparagus.

To the *Iridaceæ* (Fig. 75) belong the iris, flag, gladiolus, saffron.

The *Amaryllidaceæ* (Fig. 76) comprise the narcissus, jonquil, snow-drop.

The *Orchidaceæ* (Fig. 77) are a very curious tribe, whose flowers have sometimes very fantastic shapes: among these we find orchids and the vanilla.

The *Palmaceæ*, or *Palm family*, is found only in warm climates: it includes the dwarf-palm, rarely more than three

FIG. 74.—Liliaceæ (Tulip).

FIG. 75.—Iridaceæ (Iris).

FIG. 76.—Amaryllidaceæ (Narcissus).

feet high, the date-palm, the cocoanut-palm; and the sago-tree.

The *Graminaceæ* (Fig. 79) comprise the *cereals;* that is to say, wheat, barley, oats, rye, rice, millet, Indian corn; also the sugar-cane, bamboo, couch-grass, darnel-grass, and the greater number of good fodder-grasses.

The above are among the principal groups of flowering plants. We shall afterwards, in the course of some botanical excursions in the country, learn further details about the form and structure of these flowers, and, in short, their peculiar *characters.* We must, for the time being, content our-

selves with the foregoing dry nomenclature, which I advise you to copy into your note-books.

Fig. 77.—Orchidaceæ (Vanilla).

Fig. 78.—Liliaceæ (Asparagus).

Fig. 79.—Graminaceæ (Wheat).

VI.—Flowerless Plants.

26. There is still a great class of vegetable organisms which we have not as yet examined or spoken about.

All the plants we have passed in review *bear flowers*, sometimes reduced, it is true, to stamens and pistils.

There are plants, however, that *have no flowers at all;* and, although they are perhaps less beautiful than flowering plants, they are by no means less interesting.

27. Ferns.—The first group of these flowerless plants of which we shall take notice is that of the Ferns. The ferns of our country are small if compared with those found in warm climates, where their stems are frequently several yards high. No doubt you wonder how it happens that ferns, having no flowers, can nevertheless bear seed. Much might be said upon this question, for few subjects are more curious, or more interesting. I must, however, be content simply to

lay before you a fern leaf, gathered from our own woods (Fig. 80), and such as every one of you is acquainted with. See on the under side of this leaf, beneath each division, or, as we should say, each *lobe*, those tiny yellow specks ranged in rows (Fig. 81): they are aggregates of *sporangia*, or spore-cases.

FIG. 80.—Fern leaf. Under each lobe are little yellow specks (*sporangia*) which contain the seed.

If you examine them with my magnifying-glass, you will see that they contain minute grains (*sporangia*), which in their turn contain the seeds (*spores*) of the fern: you can imagine that those seeds are small indeed.

28. Mosses, Lichens, Mushrooms, Algæ.—After the Ferns, let us cast a glance at the MOSSES (Fig. 82). You are all well acquainted with them, and have doubtless observed amidst their foliage tiny balls B (Fig. 83), borne on long, slender stalks: these balls are cases that contain the seed.

FIG. 81.—Sporangia magnified.

Next to the Mosses are the LICHENS (Fig. 84), of which I have already spoken (page 8).

Then come the MUSHROOMS (Fig. 85), so varied in shape, in size, and in color. You are aware, of course, that some mushrooms are edible, while others are terribly dangerous, although in outward appearance they are both much alike. It is, then, most prudent to trust only to those cultivated on mushroom-beds, and never to eat those which grow wild.

Truffles are a sort of mushroom that live under ground.

What is to be seen on the under part of the lobe of a fern? What do these yellow specks contain? Where are the seeds of mosses to be found? What sort of mushrooms can alone be eaten without danger?

Some mushroom-like organisms are so very small that they cannot be discerned without the help of a microscope. Such

FIG. 82.—Moss.

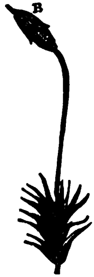

FIG. 83.—Cases containing the seed of the moss.

FIG. 84.—Lichen.

is *mould*. So also with many pests of our vineyards and fields. All these mushrooms and their allies are termed *Fungi*.

The ALGÆ (Fig. 86) are plants that live in water. Some

FIG. 85.—Mushrooms.

FIG. 86.—One of the higher Algæ (Coralline).

are very curious and very beautiful, especially among those that live in the sea.

This is all I can tell you at present of the natural history

What is mould? What are the Algæ?

of plants. In our walks we shall frequently find occasion to gain new information; and I hope to be able to show you a great many of the plants I have mentioned, and probably many others besides.

Now, before leaving the history of plants, I must tell you of the existence of very minute beings, so minute indeed that it is only with the help of the most powerful microscopes that they can be seen, yet which play in nature a most important part.

You have perhaps heard of dire maladies that kill thousands of sheep every year, and not sheep only, but also oxen, and even men. Many of these are produced by an extraordinary swarming in the body of little creatures called *bacteria*, that look like minute glass threads (see Natural History). The mere prick of a pin that has been dipped in the blood of an animal suffering from one of these diseases would be sufficient to cause death to a man.

Putrefaction also is caused by the development in dead bodies of similar little creatures. These tiny beings, and many others akin to them, exist in a dry and inert state in the dust that floats in the air; they are everywhere to be found, and when they fall upon dead animal or vegetable matter they vegetate and grow like grains of corn upon arable land.

SUMMARY.—PLANTS.

1. **Different Parts of a Plant** (p. 8).—An ordinary tree is composed of a ROOT, a TRUNK, or stem, BRANCHES, LEAVES, and FLOWERS.

2. At the axil of each leaf, in the angle that it makes with the branch, is found a BUD.

3. This bud, in growing, will produce a new branch.

4. All branches thus take origin at the AXILLA of a leaf, and every leaf bears a *bud* at its axilla.

5. Some branches, instead of lengthening out indefinitely, remain short, and are terminated by BUDS. These buds expand into FLOWERS, which give birth to the FRUIT.

6. **The Trunk or Stem** (p. 9).—The trunk of the trees of our country (with the exception of the palmetto) is composed of three parts: in the centre is the PITH, soft and white; round the pith is the WOOD, which is

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What are bacteria? What effect would be produced on man by the prick of a pin dipped in the blood of an animal afflicted with such a disease? By what cause is putrefaction produced? Where do you find these little creatures and many others akin to them? What is the cause of their development?

hard; and, lastly, surrounding the wood is the BARK, which is often green on the outside.

7. The pith does not occupy more space in an old tree than in a young one; in other words, the pith does not increase as the tree grows older.

8. The trunk of an old tree cut across presents a great number of *circles* fitting into one another.

9. Each of these circles corresponds to one period in the growth of the tree.

10. As the tree grew more rapidly when it was young, the circles near the centre of the stem are very distinct from one another; they become less and less so as they get nearer the bark.

11. As to the wood, we can distinguish between the *core* in the centre, which is harder, because it is older, and because in the course of time a solid matter has been deposited there, and the *sap-wood* (placed between the core and the bark), which is softer.

12. The trunks of our trees taper gradually towards the top, and terminate in a point: they are *conical*.

13. The Branches (p. 11).—Stems give origin to branches in a great variety of ways. Sometimes they send out horizontal branches, as in the fir; sometimes they branch out in all directions, as in the plum-tree.

14. The Leaves (p. 12).—Leaves are composed of a stalk, or *petiole*, sometimes wanting, and a green part, or *lamina*.

15. This lamina is sometimes *simple*, as in the leaf of the apple-tree; sometimes *divided*, as in that of the buttercup. It is still further divided in the leaf of the acacia.

16. The Flowers (p. 13).—The flower is composed of SEPALS, generally resembling little green leaves, the aggregate of which is called the *calyx*.

17. Next internal to these come larger leaves, generally colored, which form the *corolla;* they are called PETALS.

18. In the centre of the flower you can see little thread-like stalks, at the ends of which there are yellow masses: these little stalks are the *stamens*, and the color is produced by a very fine kind of dust called *pollen*.

19. In the very centre of the flower there are one or more balls surmounted by fine stalks. This ball is the OVARY, the stalks are the STYLES, and the whole, ovary and styles, is called the PISTIL.

20. The Fruit (p. 14).—It is the ovary that in course of time becomes the FRUIT.

21. In the ovary there are little white masses called *ovules:* these ovules will become the *pips* or *grains* that you see in the fruit.

22. Incomplete Flowers (p. 15).—The important parts of the flower are the STAMENS and the OVARIES, or rather the POLLEN-DUST and the OVULES.

23. When the stamens of a flower are removed, the development of the ovary is completely checked, and the fruit does not *knot*.

24. Certain plants bear two kinds of flowers, the one possessing stamens, and the other the pistils (ovaries and styles).

25. Sometimes the two kinds of flowers are borne on different plants.

26. Seeds (p. 17).—If you examine a seed,—a bean, for example, or the kernel of an almond,—you find two bodies called *cotyledons*.

27. Between the two cotyledons you can see a plant in miniature, in which you can distinguish a small ROOT (radicle), and a little STEM with a tiny BUD at the summit (plumule).

28. As for the cotyledons, they are the first two *leaves*.

29. Structure of the Palm-Tree (p. 18).—The trunk of the palm-tree is everywhere of the same size: it is *cylindrical*, and not *conical*.

30. The trunk of a young palm-tree is as thick as that of an old one: it *lengthens*, but does not *thicken*.

31. In these trees there is ONLY ONE BUD. It is at the *top* of the tree, at which point the plant grows. There are no buds on the sides, and consequently no branches, but simply a large tuft of leaves, stiff and hard, placed at the top of the tree.

32. There is no pith in the trunk, there are no circles of wood fitting into one another, and there is no bark.

33. Instead of all this, there is a soft mass, in which may be seen hard black fibres, which originate in the leaves and penetrate into the interior of the trunk, and then thread their way back to the surface.

34. The seed of the palm-tree has but ONE COTYLEDON. This is the case with all plants of similar structure.

35. Dicotyledonous and Monocotyledonous Plants (p. 21).—Plants have been divided into two classes, MONOCOTYLEDONOUS plants, having only one cotyledon, and DICOTYLEDONOUS, having two cotyledons.

36. In each of these classes there are trees, shrubs, and grasses.

37. Duration of Plant-Life (p. 21).—Some plants shoot in spring, flower in summer, and perish in winter: such plants are called *annuals*.

38. Others give leaves the first year, flowers and fruit the second, and then die: these are *biennials*.

39. Others flower and give fruit for several successive years: these are *perennials*. True perennial plants are generally shrubs and trees.

40. Lastly, there are plants perennial in the ROOT ONLY, and annual in the stem: such is the dahlia.

41. Classification of Plants (p. 22).—Plant *families* have been established by grouping together under the same name all those whose FLOWERS bear a great resemblance to one another. We have thus the families of the *Leguminosæ*, the *Rosaceæ*, the *Primulaceæ*, etc.

42. Plants without Flowers (p. 36).—Some plants have no flowers at all. Such are *Ferns*, whose seeds are borne on the leaves, *Mosses*, *Lichens*, *Fungi*, and *Algæ*.

SUBJECTS FOR COMPOSITION.

1st Composition (p. 9).—The stem. The pith; the place it occupies in the trunks of young trees, in those of old trees. What is implied by the rings of wood. Core and sap-wood.

2d Composition (p. 12).—Leaves. What is seen at the axils of the leaves. Simple leaves, complex leaves.

3d Composition (p. 13).—Flowers. The different parts of a flower. What the ovary becomes.

4th Composition (p. 18).—Palm-trees. Their trunk. Their leaves. Their seed.

5th Composition (p. 21).—Duration of plant-life.

6th Composition (p. 24).—What may be seen in a bean.

III.—STONES AND SOILS.

STONES.

29. Now that we have acquired some knowledge of animals and plants, we must set to work and learn something of the GROUND or SOIL on which we tread, and of the STONES, or, more properly speaking, the *minerals*, of which it is formed. You will see that here also there is much interesting knowledge to be acquired.

30. Different Constituents of the Soil.—Of course you all know that soil is composed of many different constituents. You are able, I am sure, to recognize *arable land*,—that is, *earth* which is tilled, and in which seeds are sown and plants cultivated; also *stones*, dispersed all through the soil, now in small fragments, again in great masses called *rocks;* and *sand*, in reality composed of very small stones; again, *clay*, a sort of earth easily wrought, kneaded, and moulded, which retains water in its hollows, being what is called *impermeable*, and which, when baked, becomes hard, so that, from ancient times until now, dishes and all sorts of pottery have been made with it. Lastly, all of you have no doubt seen or heard of pretty, regularly-shaped stones, having what are called *angles*, *edges*, *faces*, which stones are called *crystals* (Fig. 87).

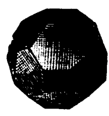


FIG. 87.
A crystal.

As we know what a classification is, we can see that this is already a pretty good beginning. Only we have learned not to depend on appearance alone. Let us, then, set to work and look closely and attentively at all these things.

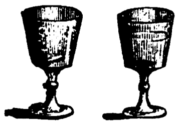
31. Action of Acids upon Stones.—Here is a bit of

What are the different constituents of the soil?

CHALK that I plunge into a glass of strong vinegar (Fig. 88). *Tiny bubbles of air* (gas is a more appropriate word) *immediately ooze out of the stone and rise to the surface of the liquid, which thus seems to boil.* Now that I have stirred the contents of the glass with a bit of stick, you can see that the chalk has entirely disappeared: IT HAS DISSOLVED, just as a bit of sugar would have done. We shall find the explanation of this in another lesson, when we come to study chemistry; we have verified the fact, and that will do for to-day.

I will now put into the vinegar a *bit of limestone*, similar to that with which houses are sometimes built: hard as this stone is, it also gives off a gas and dissolves as the soft chalk did. MARBLE would be acted upon in just the same manner.

Now, if I put a lump of CLAY (Fig. 89) into the vinegar, the result will be altogether different: scarcely any gas will be set at liberty, the clay will spread itself out at the bottom of the vessel, and will remain there perfectly intact.



A B

FIG. 88. FIG. 89. The action of acids on stones. In A, the chalk dissolves in vinegar; in B, a piece of flint remains intact.

Here is, this time, a BIT OF FLINT, also a PEBBLE I found in the bed of the river, which the water had washed down from some mountain-rock, also an agate marble: *upon these the vinegar has no effect at all, any more than pure water would have.*

Vinegar contains an *acid*, and it is the acid that dissolved the chalk or the limestone; but the vinegar contains also much water, so that the acid is not strong.

We will now repeat the experiment with a very strong acid that burns and destroys almost everything, *sulphuric acid*, often called *oil of vitriol.*

With great care, I take a drop of it on the end of a glass rod and let it fall upon the CHALK. See the rapid discharge of gas, or *effervescence*, as chemists call it.

Another drop upon this bit of MARBLE, so beautifully pol-

What happens when a piece of chalk is put into strong vinegar? Under the same circumstances what would take place with a small piece of stone used for building? Marble? A piece of clay? A bit of flint? A small pebble? An agate marble? If instead of vinegar very strong sulphuric acid were employed, what effect would it have upon the chalk? What on the marble?

ished and seemingly so hard: the effect is the same. This should teach you, by the way, never to leave upon marble an orange or a bit of apple or any other acid thing, else the marble would be very rapidly corroded.

But upon CLAY, FLINT, *the* PEBBLE, *or the* AGATE, *the sulphuric acid has not the slightest effect; the drops we let fall upon them remain quite still, and occasion no effervescence.*

There exist, then, two kinds of stones: 1. *Those that dissolve in acids, giving off gas;* 2. *Those that are not affected by acids.*

32. Calcareous and Silicious Stones.—*Chalk, limestone, and marble are called* CALCAREOUS STONES. When strongly heated in furnaces constructed for the purpose and called lime-kilns (Fig. 90), they become *lime* (in Latin CALX, whence their name). Besides, whatever be their hardness, they are never so hard as steel, nor even as iron. *Therefore a knife, or even a nail, can always make a scratch on them.* On the contrary, flint and all stones akin to it, agates, etc., *contain no lime, and undergo no alteration by fire.* Moreover, they are so extremely *hard* that the point of a knife has no effect upon them, while they, on the contrary, if they have a sharp edge, can cut marks even upon steel. Also if they are struck violently and sharply against a bit of steel, on the back of a knife, for example, a fragment of steel is detached, and is heated red-hot by the force of the blow; this heated fragment makes a *spark.*

FIG. 90.—Lime-kiln. When *calcareous* stones are subjected to a very high temperature they are transformed into *lime.*

What effect has sulphuric acid on clay? on a piece of flint? on a pebble? What classification can be established from the preceding experiments? What name is given to stones that dissolve in acids, such as chalk, common building-stone, and marble? Into what are calcareous stones transformed when subjected to a great heat? What other peculiarities do these stones possess? What becomes of such stones as flint when exposed to the action of fire? What becomes of them under the action of the point of a knife? What happens when they are struck against steel?

Long ago, and yet not so very long ago, this property was applied to *kindling fire* (Fig. 91),—striking fire, as people used to call it. For this purpose tinder was prepared by partially burning linen rags, so as to catch the spark resulting from the blow. The tinder took fire as soon as the spark fell upon it. The same principle was applied to guns (Fig. 92), the spark in like manner setting fire to the gunpowder. *All*

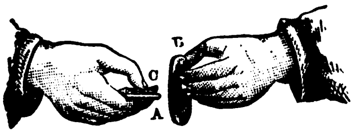


Fig. 91.—Flint and tinder. The shock of the flint A against the steel B detaches a fragment of the steel, which becomes red-hot, and is known under the name of a spark: it sets fire to the tinder.

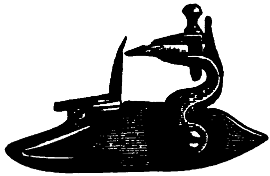


Fig. 92.—Lock of a gun. It is the spark that inflames the powder.

these extremely hard stones are SILICA, *or rather* SILICIOUS STONES. There exist a good many of them, and some are very beautiful, rare, and precious. We shall afterwards have occasion to speak about these.

SANDSTONE, which is merely *grains of sand stuck together or agglomerated*, as it is called, is sometimes slightly *calcareous*, sometimes entirely *silicious*. This last variety, on account of its hardness, which causes even steel to be worn away by it, is used to make *whetstones*.

The stones and lava thrown from volcanoes are *silicious*.

33. Plaster, Slate, Clay.—Here is a kind of stone which, although not very common, is very useful indeed. See how soft and yielding it is. I can scratch marks on it with my finger-nail. Yet a drop of acid has no effect upon it. If exposed to a strong heat (Fig. 93), it is reduced to a fine white powder, which you all recognize immediately: it is PLASTER.

By what name are these hard stones known? Does the division adopted for stones apply equally to sandstone? What is the nature of volcanic lava? What effect have acids on plaster? What is the action of fire on this material?

The stone is called GYPSUM. Great quarries of it exist near Paris; and for this reason the plaster it affords is sometimes called *plaster of Paris.*

A fine-grained, very compact sort of gypsum, called *alabaster*, is found in Italy, where great numbers of statuettes are cut from it (Fig. 94). It is usually white, but sometimes is yellowish, reddish, or gray.

Slate (Fig. 95) is well known to everybody; its hardness is about equal to that of calcareous stones; that is to say, scratches can be made on it with a knife. The finger-nail cannot mark it, and acids have no effect upon it.

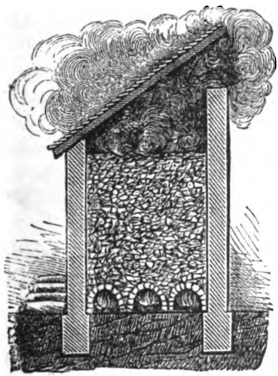


FIG. 93.—An oven for burning plaster. *Gypsum* subjected to a great heat becomes plaster.

FIG. 94.—Statuette in alabaster.

FIG. 95.—Man working at slate.

Clay is, as everybody knows, soft and easily moulded into any shape, yet acids have no effect upon it.

Limestone, Sandstone, Gypsum, Slate, and Clay *are the most useful stones, or at least the most useful for you to know about.*

34. Stony Mixtures.—You must not, however, imagine that the rocks are always pure in their composition, or that they are distinct one from another. On the contrary, *calcareous rocks* generally contain some clay, while clay contains more or less calcareous matter. For instance, there is a well-

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What name is given to plaster? What name is given to a very fine sort of gypsum that is found in Italy? What is to be said about slate? About clay? Name the principal kinds of stones. Are calcareous rocks and clay always pure?

known rock called MARL (Fig. 96), which is composed of *calcareous* matter mixed with a large proportion of *clay*. It

FIG. 96.—The *marl* that is spread on fields is a calcareous rock mixed with a large proportion of clay.

is, in fact, for this reason that frost breaks it up so easily, and allows the rain to dilute and mix it with the soil, to which it is applied as a fertilizer.

What is known by the name of VEGETABLE MOULD, or ARABLE SOIL, is only a *mixture* of different kinds of stones reduced to fine powder and mingled with animal and vegetable matter. See, here is some garden-mould quite freed from stones. Let us wash it carefully by shaking it gently under the tap of the water-cask (Fig. 97). The water that runs off is muddy and dirty; it carries along with it a quantity of blackish matter. At last, by dint of shaking, nothing remains but some very fine and tolerably clean sand in the bottom of the glass. We will now add a little sulphuric acid. Immediately effervescence ensues, and this indicates the presence of *calcareous* matter. Everything has settled down again, and you see there still remains in the glass a good deal of sand. This we

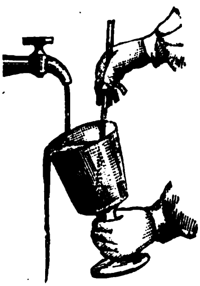


FIG. 97.—Vegetable mould, or arable soil, is a mixture of calcareous powder, grains of silex, clay dust, and animal and vegetable remains.

What is *marl?* What is the composition of arable or vegetable soil?

can affirm is composed exclusively of grains of *silica* and *clay dust.*

35. Crystals.—Minerals, as I have already told you, often assume the form of what are called CRYSTALS. There are, for example, *calcareous* crystals and *silicious* ones. *Gypsum* is often found crystallized in a spear-head shape (Fig. 98). Crystals of carbonate of lime (Fig. 99) are of no value. One day a poor countryman came, almost mad with joy, to tell me he had discovered a mine of diamonds. His diamonds were simply some calcareous crystals that lined the interior of a large hollow stone. Great was his grief when I told him what his treasure really was, nor would he entirely believe me until I showed him that with my knife I easily cut marks upon them.

FIG. 98. Crystal of Gypsum.

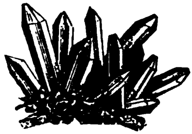


FIG. 99.—Calcareous crystals.

One of the most interesting among crystalline calcareous rocks is the white and beautiful *statuary marble* (Fig. 100). A broken fragment of this marble looks just like a bit of lump-sugar: in fact, like lump-sugar, it is composed of an assemblage of tiny crystals closely interlaced.

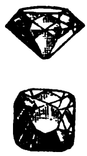
FIG. 100.—Marble statue.

FIG. 101.—Enormous rock-crystal in the Jardin des Plantes of Paris.

Silicious crystals are much prized on account of their great hardness, which enables them to cut marks upon glass, while it prevents them from being dulled like calcareous crystals.

Under what form are minerals often found? Does the division adopted for stones apply also to crystals? What is the value of crystals of carbonate of lime? Name an interesting calcareous crystalline rock. Why are silicious crystals more sought after than calcareous crystals?

One of the most common is QUARTZ, or *rock crystal* (Fig. 101), sometimes found in crystals as large as a man's head.



Other rarer crystals, of more brilliant aspect and still harder than quartz, are found only in small crystals, and are eagerly and carefully sought out, and cut with facets to serve as jewels.

They are called PRECIOUS STONES: *rubies* (red), *sapphires* (blue), *emeralds* (green), *topazes* (yellow), *amethysts* (violet).

FIG. 102.—Diamonds artificially cut. Diamonds are pure crystallized carbon.

Before passing on to more useful matters, I must tell you something about DIAMONDS (Fig. 102).

The diamond is the most beautiful of all crystals, the most brilliant and the hardest; it can cut glass or engrave upon all other crystals. Being the most

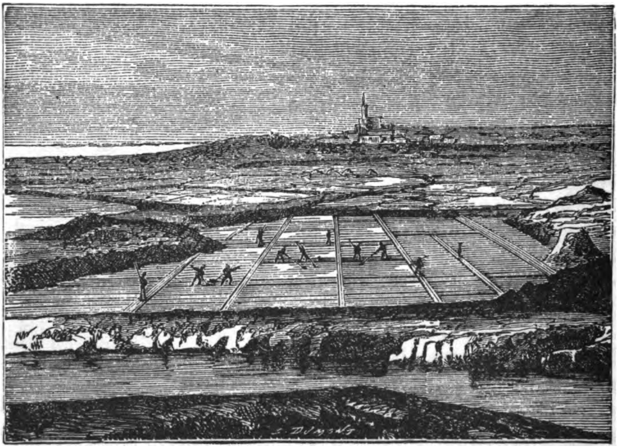


FIG. 103.—Salt marsh, where salt is obtained by the evaporation of sea-water.

precious, it is of course also the most expensive: a diamond

Name a common silicious crystal. Mention some silicious crystals that are much sought after for jewelry.

weighing 15 grains is worth at least a thousand dollars. And yet it is not a stone; it in no wise partakes of the chemical nature of other minerals. It is pure crystallized *carbon*, which is the scientific name for charcoal. This is an astonishing and almost incredible fact, on which we shall acquire some further information in our lessons on chemistry.

For the time being, keep in mind this one fact: *a diamond can be burned just like coal*, only it requires a stronger heat.

All the above-mentioned crystals are very beautiful indeed, but of little real use. Others, on the contrary, are of very great utility; such as *salt*, for instance, our common kitchen salt.

A great quantity of the salt we use is obtained by the evaporation of sea-water, in SALT MARSHES (Fig. 103). But this is not the only way in which this indispensable article is procured. Immense crystallized masses of it are found in the earth (Fig. 104): it then takes the name of ROCK-SALT.

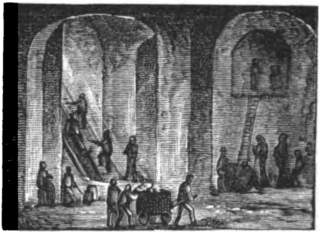


FIG. 104.—Mine of rock-salt.

The most important salt-mine in the world is that of Wieliczka in Poland; in this mine, 600 feet under ground, miles of galleries have been made: this will give you some idea of its extent and importance.

36. Crystalline Rocks.—Crystals are not always isolated. They are sometimes collected together in masses considerable enough to form stones and even rocks.

GRANITE (Fig. 105) is formed in this manner. All of you, I am sure, have seen granite. It is composed of three sorts of crystals interwoven together,—namely, QUARTZ, of which we have already spoken, FELSPAR, and MICA.

Is the diamond calcareous or silicious? What is the diamond? How do you prove that the diamond is carbon? Name a crystal less handsome than the preceding ones, but more useful. From what is salt extracted? Is salt found only in sea-water? Name the three kinds of crystals of which granite is composed.

MICA also is something with which most of you are familiar. In some countries the sea washes it ashore in such quantities that it is gathered and sold for next to nothing under the name of *gold powder*, which is used to dry up ink instead of blotting-paper. See, I have some here: it looks like a great many thin and brilliant spangles of gold. Sometimes this same substance is found in sheets large and transparent enough to be used, in certain countries, as window-panes. Because heat does not crack it, it is used in the doors of stoves.

FIG. 105.—Fragment of granite, a mixture of quartz, felspar, and mica.

FELSPAR (Fig. 106) is less spoken about. It is, notwithstanding, of no small importance. Often it decomposes and crumbles into dust. This dust, carried away and washed by the rain, becomes what is called *kaolin*, from which *porcelain* is manufactured. Kaolin is only perfectly pure clay.

There exist a great number of rocks more or less akin to *granite*. Those best known among them are the PORPHYRIES,

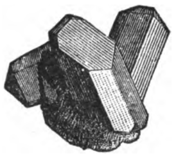


FIG. 106.—Fragment of felspar, which, under certain influences, becomes kaolin, of which porcelain is made.

FIG. 107.—Fragment of basalt.

composed of the crystals of felspar set in a fine paste of felspar, like almonds in an almond-cake, and BASALTS (Fig. 107), of volcanic origin.

We have now passed in review the principal rocks and stones, hard, soft, crystalline, or otherwise. But we cannot

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Where is mica found? What is done with it? What becomes of felspar when decomposed and reduced to dust? What is made of kaolin? Among the best-known rocks name two akin to granite.

leave the history of things found in the crust of the earth without saying a few words about METALS and COAL.

37. Metals and Coal.—METALS are generally found in the form of ORE; that is to say, mingled with other bodies. Although sometimes found on the surface of the ground, they are generally more or less deeply buried, necessitating

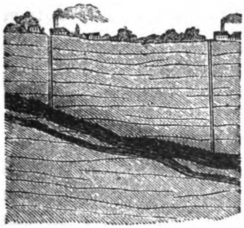

FIG. 108.—A section showing a metallic vein in the earth worked by means of mines.

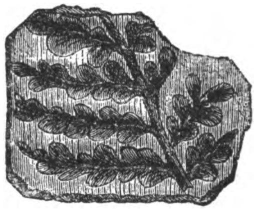

FIG. 109.—A fragment of coal bearing the impression of a fern-leaf.

the hollowing out of *mines* for their discovery and extraction. The *ore* exists in the earth sometimes in pretty large masses, sometimes in VEINS (Fig. 108), which the miner must carefully follow up, as one would follow the pipe of a stove in order to remove the soot.

FIG. 110.—Interior of a coal-mine.

It happens at times that rocks containing *ore* crumble to pieces from the effects of frost and rain, and then are rolled away and broken up by torrents and rivers. The metal, being heavy, *falls* to the bottom in deep pools and quiet nooks. This is why gold is often found in the former beds, as well as in the actual channels, of certain rivers.

Where are metals found, and in what condition? What do they form in the earth?

COAL is the residue of *vast forests* buried in the earth during an immense number of years. Those forests were composed mostly of enormous ferns (Fig. 109) and trees somewhat akin to our firs. In order to get the coal out of the depths of the earth you know that great pits called *mines* are dug, and subterranean galleries are made (Fig. 110).

The TURF or PEAT in formation at the present day *is very young coal* not yet buried. The plants of which it is composed are still recognizable.

ROCKS.

Calcareous stones, clays, slates, silicious stones, are not found mingled together in a hap-hazard fashion in the soil on which we tread. No; you already know that this is not the case.

And before proceeding further I must acquaint you with the fact that the term *rock* is applied by mineralogists not only to the stony matter familiarly called *rock*, but also to all the massive mineral substances which compose the crust of the earth, be they as soft as clay, as easily broken as chalk, or as hard as flint.

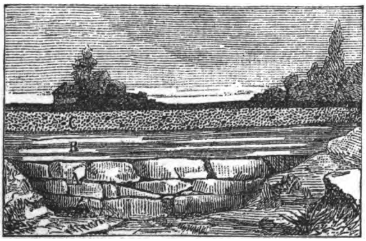

FIG. 111.—An open quarry. A, calcareous stone; B, clayey earth; C, sandy soil.

38. In one of our recent walks we went to visit the quarry on the hill-side. You may remember I pointed out to you the lowest part of the excavation, A (Fig. 111), formed of *calcareous stone*, commonly called limestone, of which the village is built. Above these we saw a layer B of clay which supplies material for tile- and brick-works. And lastly, upon the top, there was a layer C of sand, bestrewn with pebbles like those you find in the river at the foot of the hill.

What is coal? What is peat?

The neighboring hill is composed of three superposed layers, —namely, *calcareous* rock, *argillaceous* rock, and *sandy soil.*

39. *Beds or Layers.*—As we made a pretty long visit to the calcareous or limestone quarry, I called your attention to the fact that the *blocks of stone were arranged with perfect regularity, one upon another*, just as if some giant had carefully piled them up. From place to place I showed you horizontal bands separating *layers of stone*, slightly differing from one another in color and hardness. In other words, I made you observe that the quarry *was formed of several regularly superposed* STRATA.

In climbing the steep road cut on the slope of the hill we passed the precise spot where the calcareous strata ended and the layer of clay began. There, also, *we saw that the line of separation was as straight and level* as the lines which divided the different strata in the stone-quarry.

Now, what do you think could have brought such a collection of stones there, and how does it happen that they are so neatly and so regularly arranged?

40. Marine Organisms in Rocks.—The question certainly appears a very difficult one. But here is something that will help us to find an answer. The owner of the quarry gave us some fossilized shells, and those of you who went climbing about everywhere found here and there great numbers of them: these are *shells changed into stone.*

FIG. 112.—Fossil oysters.

Let us examine these shells (Fig. 112). At a glance we can detect their resemblance to common oysters. And oysters, as you well know, live in sea-water. Hence the conclusion that the *sea once lay above our quarry;* that these oysters lived in it, as those of our days live on

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What name is given to all the different kinds of massive mineral substances that form the crust of the earth? Are the different kinds of stone in a quarry all mingled together? What are often found in quarries? What does the presence of these shells, changed into stone, prove?

the rocks under the waves; that after the death of these oysters, slimy mud and sand of a calcareous nature were deposited on their shells; and that after all this a time came when the sea disappeared, *when the mud, sand, and shells stuck together in the process of drying, and formed thus the calcareous stone we have now before us.* Things cannot be explained otherwise. Moreover, it has been proved that the like is now going on in several places on the sea-shore.

41. Apparent Movements of the Sea; Movements of the Ground.—But, you may ask, how can it be that the sea, which is far off at the present day, should have at one time covered with its waves a great part of our hill, and risen so far above its present level? And again, if it once was there, how is it that it has so completely disappeared?

There are only two ways of explaining this.

The first would be to suppose that there was at one time much more water in the sea than there is now, and that its level was therefore higher than at present. And yet that would not suffice, for marine shells are found in the Alps and Pyrenees at more than 9000 feet above the level of the sea. And again, if this were the case, what could have become of such an immense quantity of water? Could it have evaporated into the air? The firmament would not suffice to hold so many clouds. Could it have sunk into the earth? We shall hereafter see that it is far too warm for water to remain there. This cannot, then, be the real solution.

The second explanation would lead us to suppose *that it is the* BOTTOM *of the sea that has been* HEAVED UP *so as* TO EMERGE OUT OF THE WATER, *which latter has changed place without diminishing in quantity.*

Which of the two explanations do you prefer?—"I see that the first will not do. And for the second, I cannot see how it could do either. The earth is so solid! Papa, who has been on the sea, says that the water is constantly in motion; while on dry land everything is quite still and steady."—Well, let me tell you that the dry land is not so still nor so steady

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What becomes of the mud, sand, and stones when consolidated in a mass? How do you explain the occurrence of marine shells at the present day considerably above the level of the sea?

as you imagine. True, its movement is so slow that we do not feel it. But *it rises here and falls there, and in some places it rises and falls alternately.*

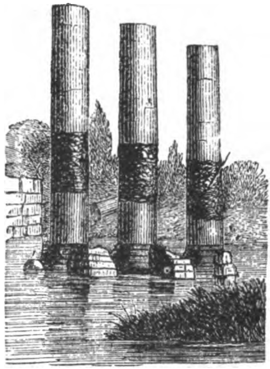

FIG. 113. — Temple at Pozzuoli, in Italy. B, marine boring shells, indicating that the earth had once sunk to this depth below the sea.

Obvious proofs of this exist at the sea-side in various places. At Pozzuoli (Fig. 113), in Italy, the Romans built a temple on the sea-shore. The ground having subsequently sunk, the sea invaded the temple long enough to allow marine shells to burrow into the columns some yards above the pavement. Since then the ground has again risen, and at the present day the traces of the marine shells are at a considerable height above the water. The same phenomenon is taking place slowly in our days on several coasts. The coast of Norway, for instance, is sinking gradually, while that of Sweden is emerging more and more, and the Baltic is becoming shallower. Landmarks made on the Swedish coast by the celebrated naturalist Linnæus at the beginning of the eighteenth century, show that this upheaval raises that coast about four feet in the course of a century. There is nothing surprising, then, in the fact that the bottom of the sea should have been many feet above its

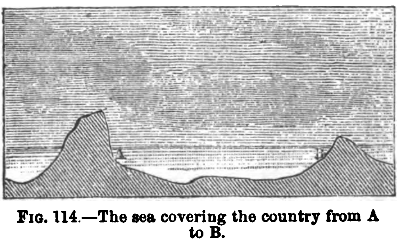

FIG. 114.—The sea covering the country from A to B.

Is the ground on which we walk immovable? Give a modern example of changes in the position of land.

actual level. Many centuries have passed away since that time. But *centuries*, which to us seem so long, are but *moments* when compared to the immense periods of the past.

In short, science makes us sure at the present day that the second explanation is the true one. The sea came this far formerly, covering all the surrounding country from A to B (Fig. 114), and depositing regularly and slowly its material held in suspension and its shells. Afterwards the bottom of the sea was upheaved, and A′ B′ (Fig. 115), with all its solid sediments, became dry land. Do you understand now?

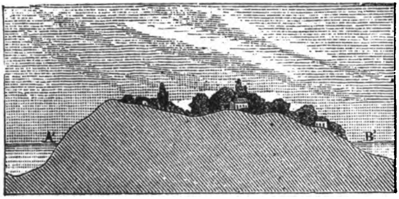

FIG. 115.—Then the bottom of the sea rose to A′ B′.

42. Differences between the Superposed Strata.—But why is it that the limestone-beds are not alike from top to bottom of the quarry, and that there are, as you told us, *several strata? It is very probable that during this uprising of the bottom of the sea the rivers and currents did not always bring along with them the same kind of matter, and did not deposit their sediments in the same place.* For we can ourselves observe similar though smaller changes where the waves deposit alternately on the same part of the sea-shore fine sand and large pebbles.

FIG. 116.—A few fossils.

43. Fossils.—More than this. *During* the IMMENSE LENGTH OF TIME *that this upheaving continued, even the nature of animals* has changed. In the same place, but at a different height, the species, or rather their remains, are not alike. In our quarry we find

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Do these changes take place quickly or slowly? Why is it that on the limestone there are placed different successive strata? What other phenomenon is produced during the enormous duration of time required for these upheavals?

not only oysters but also many other kinds of marine molluscan shells (Fig. 116). Now, in the upper strata these FOSSILS, as they are called, differ notably from those found in the lower.

44. Real Divisions of Stratified Rocks.—We must, then, divide such rocks *not only according to the nature of their component stones, but also, and especially, according to the nature of the* FOSSILS *found in them.* For at sea-side places, at no great distance from one another, sometimes clayey substances are to be met with, sometimes calcareous deposits. Only, the inhabitants being the same, the shells are so also, and would form the same kinds of fossils. Thus, on the opposite side of the valley there is sand containing fossils exactly the same as those found in the upper strata of our quarry. We may hence conclude that they were deposited there AT THE SAME period, generally speaking, as those we found in the stone-quarry.

45. Causes of the Movements of the Ground.—And, now, does this satisfy you? Is there anything else that puzzles you?—"Yes, there is."—Ah! what now?—"Well, I should like to know what can move and heave up the earth so. It must be very heavy, and require enormous strength." —Ah! this is really difficult to answer. And the most learned know but little on the subject, and have been reduced to make suppositions.

FIG. 117.—Earthquake.

It is more than probable that the cause which thus gently and slowly upheaves the crust of the earth is the same as that which occasions from time to time EARTHQUAKES (Fig. 117) *in some parts of the world.* In 1881 one of these terrible commotions destroyed a town in the island of Chio, and killed a great many of its inhabitants. In August, 1886, Charleston, South Carolina, was almost destroyed in the same

What name is given to the petrified remains of animals during these different periods? How must rocks, then, be classified? What is the cause that makes the earth rise and sink so slowly?

manner. The dry land in such circumstances is about as much in motion as the heaving seas.

Earthquakes are especially common in the vicinity of volcanoes,—in South and Central America, for instance, also in Asia Minor and the south of Europe. The neighboring volcano generally breaks out into eruption simultaneously with an earthquake (Fig. 118).

You have all seen a kettle-lid jump up and down when the water boils too quickly. Well, it seems as if the earthquake were the leaps of the lid, and the eruption of the volcano the escaping of the steam, carrying with it what happens to be inside. Only it is on a larger scale. And then it is not a little boiling water that is expelled, but immense stones that are projected, and enormous volumes of steam and lava, melted by the great heat of the volcano. The lava-streams flow slowly over the ground, covering up and destroying everything they meet.

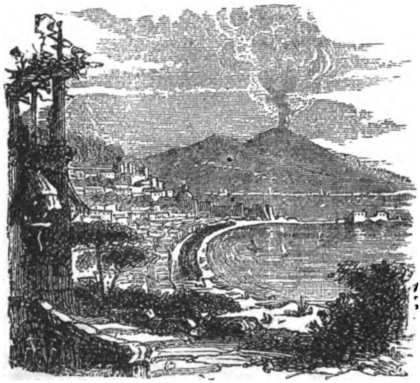

FIG. 118.—Volcanic mountain (Vesuvius) in eruption.

Some volcanoes now extinct vomited lavas different from those thrown up by volcanoes now in activity. Those lavas are called *basalts* and *trachytes*. The different kinds of *porphyry* have also been brought up out of the very bowels of the earth, and more or less spread out on the surface.

46. Igneous and Aqueous Rocks.—In short, you see, from what I have just been telling you, that there are two sorts of rocks: 1. *Rocks or soils formed by water*, or ROCKS

What countries are most exposed to earthquakes? What phenomenon often accompanies earthquakes? What are the two principal classes of rocks?

OF AQUEOUS ORIGIN (from the Latin *aqua*, water); 2. *Rocks formed by matter brought to a state of fusion by a very high temperature*, or ROCKS OF IGNEOUS ORIGIN (Latin, *ignis*, fire).

47. Salt-Water Rocks, and Fresh-Water Rocks.—Among the *rocks of aqueous origin*, some have been deposited by sea-water, others by fresh water from large lakes. They can be distinguished from one another by the *fossils* they contain. Those found in the former resemble more or less the marine animals still in existence; while those of the latter are like fresh-water shells and fishes. There are also the remains of land-animals.

When an animal dies upon land it becomes *putrefied*, and in a short time nothing remains but the bones. These in their turn, attacked by insects, water, air, frost, and the heat of the sun, decay, and in no great time disappear also. If, on the contrary, the dead body be carried away by a river so as to fall into the deep and tranquil water of a lake, it sinks to the bottom and is covered up with mud; *its bones become mineralized* (*turned into stone*), *and remain as* FOSSILS when the waters of the lake disappear. This can also happen in sea-water, but not so readily, on account of the constant motion of the waves, etc.

Therefore, *it is especially in fresh-water rocks that the remains of terrestrial mammalia, of birds, and of reptiles are found.*

It is easy to understand that no fossils are found in *igneous* rocks, since these have been thrown from the burning depths of the earth.

48. Order of Superposition of Rocks.—People who study the history of the earth, and who are called GEOLOGISTS (from the Greek, *gê*, earth; *logos*, study), have distinguished, *by the examination of fossils*, a great number of strata, to which they have given names, and which they have classed according to their relative ages.

When one rock covers another, it is certain that the upper is of more *recent formation*.

What distinction is made between rocks of aqueous origin? In what class of rocks are fossils found? In what class of rocks are fossils never found? By what means have geologists classified the different strata?

Now, rocks lie in *regular strata*, like leaves of books piled one on another. The oldest known of these rocks are crystalline, and contain no fossils (Fig. 119, A, B).

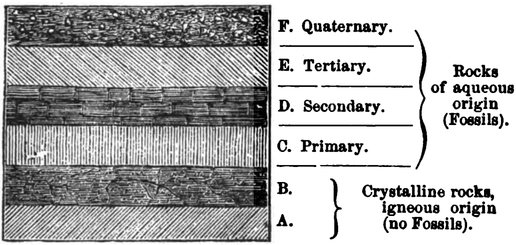

FIG. 119.

Above these come *rocks, undoubtedly deposited by water*, in which are to be found the remains of organisms of the animal and vegetable kingdoms.

The more ancient the soils are, the greater are the differences between the animals whose remains are found in them and those that people the earth at the present day.

In those beds immediately above the ancient crystalline rocks, but few fossils are to be found, and those met with belong to the lowest groups of the animal kingdom. Then, as the strata rise one over another, and as we near the present epoch, the animals appear more and more highly organized. Monkeys and men are of quite recent date.

Let us understand each other, however: "recent" in regard to geological epochs they certainly are; that is to say, they appeared last. But if we wished to count by years, centuries, thousands of years, the length of time since man existed on the earth, we should find the task too great and the length of time incalculable. And in geology it is always thus. One can say this rock is of more recent formation than the one under it, and more ancient than that which is above; but at what epoch it was formed, and how long a time its

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What is the result of the antiquity of rocks, so far as the animal species is concerned?

formation lasted, no one can tell. There are some limestones composed of shells so very small that the naked eye cannot discern them, millions of these shells existing in a cubic inch. Yet these rocks are in beds hundreds of yards thick: think, then, how many centuries must have rolled by during the formation of such a deposit!

49. Principal Formations.—Thus, it is in the most recently formed rocks, which you will find designated in books under the name of QUATERNARY *rocks*, that for the first time remains of man or traces of human industry are found.

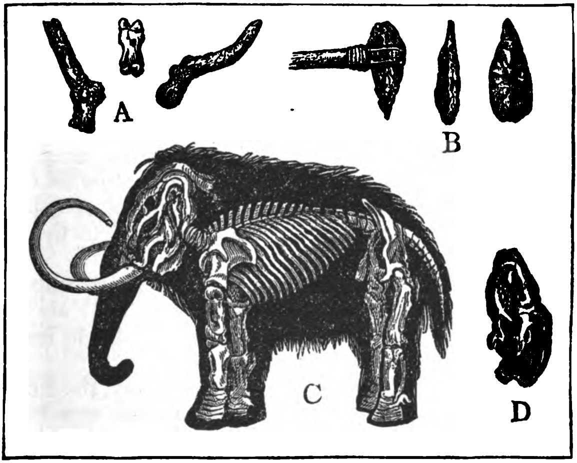

FIG. 120.—A, bones of reindeer, carved; B, axes cut out of flint; C, skeleton of a mammoth; D, skull of an enormous bear.

And a very poor industry this at first was. Man in those times lived wild, in caves along river-banks, roughly hewing silicious stones for weapons.

He had to battle, even on what is now European ground, with *elephants*, *mammoths* (Fig. 120), *rhinoceroses*, *tigers*, and gigantic *bears*. Naked and almost unarmed as he was, he

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In what rocks are found human remains and traces of human industry?

slew them and made food of their flesh, utilizing even their bones for the manufacture of various utensils. All this took place thousands of years before history existed to record his life, his struggles, and his victories.

In the earlier, or TERTIARY epoch, the end of which saw *monkeys* appear, perhaps even *man*, there were in Europe very large lakes of fresh water, upon the shores of which

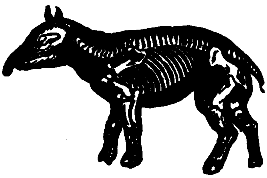

FIG. 121.—Palæotherium (size of an ass).

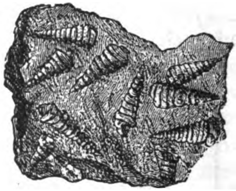

FIG. 122.—Fossil shells in a fragment of Paris rock.

lived numbers of Mammalia, widely different from those known in our day (Fig. 121). The French naturalist Cuvier first gathered together and studied their bones, and thereby was enabled to describe animals that had lived in those far-distant times.

It is on tertiary soil that London and Paris are built; and in this great numbers of *fossil shells* (Fig. 122) are to be found, similar to those existing at the present day in brackish and salt water.

During the epoch that preceded this, namely, the SECONDARY period, great parts of England and France were covered

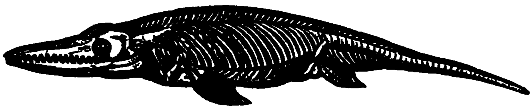

FIG. 123.—Ichthyosaurus (medium size, twenty feet).

by the sea. At that time there lived in its waters *mollusks*, *fishes*, and *reptiles* unknown in our days,—the finned reptile called *ichthyosaurus* (Fig. 123), for instance, which was not

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What epoch preceded the quaternary epoch? What epoch preceded the tertiary epoch?

unlike a whale. The remains of very few terrestrial animals have been handed down to us through these centuries, but strange are the few that we know. Here is a flying reptile, something like a bat, the *pterodactyl* (Fig. 124). Only one bird of that remote period is known, and it had teeth and a long jointed tail like a lizard.

More ancient still than the preceding are the PRIMARY rocks, C, of which the most important for you to learn about are those containing *coal:* they are called *coal-measures.* At this epoch great *forests* covering wide extents of ground were buried, so to speak, under water, and there slowly transformed into coal. Coal is very widely distributed throughout the United States, Pennsylvania supplying the greater portion, and nearly all the anthracite, or hard coal. The principal coal-mines in England are those of Newcastle and South Wales; in France, those of St. Etienne in the Department of the Loire, and those of the Department of the Nord, which last are in the vicinity of the great Belgian mines. Almost everywhere coal must be brought up from great depths, as the coal-measures are often covered by the secondary and even tertiary strata. The coal-measures of the United States are not generally so deep as those of England. Slates occur usually among rocks still older than the coal-measures.

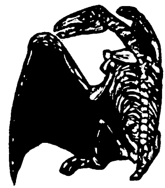

FIG. 124. — Pterodactyl (size of a pigeon).

This is all that need be said on this subject for the present course of lessons. I hope you have properly understood all I have told you, so I shall review rapidly.

First, there are the very ancient *crystalline rocks*, B, superposed in regular layers; then rocks of aqueous formation,—*primary*, *secondary*, *tertiary;* lastly, the *quaternary* rocks, which make a category apart, and on which much might be said.

50. Changes in the Map of North America.—If I have made myself clearly understood, you should be convinced

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What epoch preceded the secondary epoch? In what order do the different rocks succeed one another, beginning with the most ancient?

that since the origin of the world the aspect of the earth has undergone marvellous changes. *Oceans have taken the place of what was, in most cases, dry land; and what is dry land nowadays was, in most cases, the bottom of oceans that have been upheaved.*

Practically, all North America has been submerged once or several times; the sea encroaches here, recedes there, and sometimes reinvades regions that had formerly been lifted above its level. I here show you two maps that indicate

Fig. 125.—Map of North America during the Secondary epoch.

Fig. 126.—Map of North America during the Tertiary epoch.

The white portions represent dry land, the shaded portions represent submerged parts.

the state of land and water in North America during the secondary (Fig. 125) and tertiary epochs (Fig. 126).

51. Is there Anything under the Ancient Crystalline Rocks?—And, now, has any one any other observations to submit, or any other question to ask? What do you wish to say?

"Please, do the crystalline rocks go to the very bottom of the earth, or is there anything under them?"

Ah! you ask me questions that are hard to answer. What there is under these ancient rocks no one ever was able to see, as I have already told you. But the volcanoes seem to reach very far down into the earth, and the lavas they throw out undoubtedly come from enormous depths.

In that case, the interior of the earth would be *lava.*—

Has the earth always presented the same aspect as it now does?

"But the lava is fearfully hot: how is it that it does not heat all the earth so as to scorch our feet? And how does it come to be so very hot?"

52. Central Heat and the Crust of the Earth.—Well, follow attentively what I am going to tell you. When a deep hole is made in the ground, the *deeper it is made the greater the heat is at the bottom.*

In a mine 3000 feet in depth it has been ascertained that the *increase of heat was one degree Fahrenheit in 55 feet.* That makes 54 degrees for 3000 feet. If the same progression continued thus for 300,000 feet, the temperature would attain 5400 degrees. This is far more than is necessary to melt lava, granite, etc. Serious investigations and study lead to the belief that matter in a state of *fusion* would begin at the depth of 150,000 feet, *were not the pressure so great as to prevent actual melting.*

Now, geography has already taught you, and we will study this question also, that the earth is a globe whose diameter measures about 8000 miles. You see, then, *that this globe is almost entirely in a highly heated state, with but a comparatively thin cold crust all around*, which crust does not represent more than the hundredth part of the total thickness of the globe. *This is much less in proportion than the thickness of an orange-skin compared to the orange.*

The term "crust of the earth" is, indeed, applied only to that part of which geologists have accurate knowledge.

53. Some Explanations of the Changes that the Earth has Undergone.—It is very certain that there was a time when our earth was a ball of melted matter, still luminous, somewhat like red-hot iron. Gradually the earth grew cooler by turning and rolling through space, the materials became more compact, and a first crust was formed, composed perhaps of *granite* and *crystalline rocks.* When this crust by the progress of cooling grew thick enough to prevent the surface from being burning hot, water was formed, and became seas and oceans, and, the heat diminishing still more, living beings

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Is the temperature of the earth the same at the bottom of a deep mine as it is on the surface? In what proportions does the heat augment? Reckoning thus, what would be the temperature at a depth of 300,000 feet?

appeared. These oceans driven hither and thither on the surface of the globe by the movements of the terrestrial crust, thinner and less solid than it is now, deposited the rocks of which I have spoken to you, and with them their fossil contents.

The same thing continues to this day, but with less energy and activity as the thickness of the crust increases.

During those periods long passed away, great movements took place in the ground,—upheavals, depressions, fractures, or rents. In mountainous countries the strata, deposited quite flat by the sea, were sometimes upraised to an almost vertical position. The interior of the earth has, notwithstanding the crust, always been in communication with the outer parts. Melted matter has been thrown out, and is so still from time to time. At first it was great quantities of matter, such as the *porphyries*, that came to the surface through the thin crust they broke open. At a later period volcanoes threw out *basalt*, and nowadays they eject *lava*.

This is the history of our earth. It is no fiction, in which imagination and invention play the first parts, as they have so often done in similar circumstances, but real history, of which science is as sure as it is possible to be about things no eye has seen, and on which one can but reason.

SUMMARY.—ROCKS.

1. **Different Kinds of Stones** (p. 44).—Stones may be roughly divided into two classes: 1. Stones that dissolve in acids, giving off gas; 2. Stones that remain unchanged by acids.

2. The former, among which are to be numbered *chalk, limestone,* and *marble,* are designated by the name of CALCAREOUS STONES, because when submitted to a very high temperature they become *lime* (in Latin *calx*).

3. The latter, the principal type of which is *flint,* are for the greater part SILICA, or rather SILICIOUS STONES. They resist the action of fire, and are extremely hard.

4. Clay is numbered among silicious stones.

5. **Stony Mixtures** (p. 47).—The different kinds of stone are frequently mingled together.

6. MARL is a *calcareous* stone in which exists a large proportion of *clay.*

7. ARABLE SOIL is a mixture of *animal* and *vegetable* remains, tiny *calcareous* stones, grains of *silex,* and *clay* dust.

8. **Crystalline Stones** (p. 49).—Minerals are frequently seen under the form of *crystals*. There are *calcareous* crystals and *silicious* crystals.

9. *Calcareous* crystals, as well as *gypsum* crystals, are of little value, because, being comparatively soft, they are easily scratched and tarnished.

10. *Silicious* crystals are much prized in such forms as *quartz* or *rock-crystal*, which is not very rare, and *precious stones* (rubies, sapphires, etc.).

11. The DIAMOND, the most beautiful of all gems, is not a stone: it is pure and crystallized carbon.

12. **Crystalline Rocks** (pp. 49 and 51).—Crystals are sometimes agglomerated, forming stones and even rocks.

13. The GRANITE upheaved from the bowels of the earth is composed of three kinds of crystals,—*quartz*, *felspar* (which gives *kaolin*), and *mica* (of which the so-called *gold powder* is made).

14. PORPHYRY, which is also of *igneous* origin, is composed of crystals of felspar set in a fine paste of felspar.

15. The BASALT, of igneous origin, was projected from volcanoes, just as *lavas* are now thrown out of volcanoes still in action.

16. **Metals and Coal** (p. 53).—METALS are found under ground, where they form *veins*.

17. COAL is the residue of vast forests buried during an immense number of centuries.

18. PEAT is a sort of very young coal, as yet unburied.

19. **Rocks** (p. 54).—The limestones, the clays, the slates, and the sandstones are not all mixed together. They are disposed more or less regularly in *layers* or *strata*.

20. These layers, with the fossils they contain, have enabled us to establish a classification of the different rocks or soils.

21. In the first place we must distinguish: 1. The rocks of IGNEOUS (*ignis*, fire) origin; 2. The rocks of *aqueous* (*aqua*, water) origin.

22. The rocks of *igneous* origin have been formed by matter in fusion at a very high temperature, thrown up from the depths of the earth. They comprise GRANITE, PORPHYRIES, BASALTS, and other LAVAS. No fossils are found in them.

23. The rocks of *aqueous* origin have been deposited by the water of the SEA, and also by *fresh* water. We distinguish among them:

1. The PRIMARY rocks, above ancient *crystalline* rocks. During this period great forests that covered the ground were submerged and slowly transformed into *coal*.

2. The SECONDARY rocks, superposed on the primary ones. In those days the sea covered a great part of our country. Reptiles unknown to our epoch (ichthyosaurus and pterodactyl) have left their remains in the deposits then formed.

3. The TERTIARY rocks. During this period there lived a great number of mammalia very different from any existing at the present day.

4. The QUATERNARY rocks, in which, for the first time, human remains or traces of man's industry are to be met with, remains that were deposited on the soil of our country long before history began.

24. **Movements of the Soil** (p. 56).—The ground is ever in motion, continually being upheaved in one place and sinking in another, but so very slowly that the movement is imperceptible.

25. Things have always been going on thus. Therefore the distribution

of land and water on the surface of the globe has undergone many great modifications.

26. Under the influence of pressure exerted from within, analogous to that which gives rise to earthquakes at the present day, the bottom of the sea has been *upraised* in certain places, thrusting off in all directions the water the uplifted bed could no longer contain. In other places the soil that emerged from the waters sank down, and was covered by the waves.

27. But what an immense length of time rolled by during these changes! Centuries, that look so long, are but as minutes compared with these enormous periods.

28. In our days similar phenomena are taking place on the coasts of Norway and Sweden: the Swedish coast is sinking, while that of Norway is rising; the Baltic is becoming more and more shallow.

29. Central Heat and the Crust of the Globe (p. 67).—When a very deep hole is made in the earth, it has been remarked that the temperature gains at least one *degree* of heat every time the hole has been deepened 55 feet. So at the depth of 300,000 feet the temperature would reach 5400 *degrees* Fahrenheit. This is more than would be necessary to melt lava, porphyry, etc.

30. This leads to the conclusion that the whole earth is, internally, in a highly-heated state, and that the comparatively cool crust upon which we dwell is, in proportion, much less than the thickness of an orange-skin relatively to the orange.

SUBJECTS FOR COMPOSITION.

1st Composition (p. 45).—Calcareous stones and silicious stones. Action of acids on both. Gypsum. Slate.

2d Composition (p. 48).—Composition of arable ground.

3d Composition (p. 49).—Calcareous crystals and silicious crystals. The diamond.

4th Composition (p. 51).—Granite. Porphyry. Basalt.

5th Composition (p. 53).—Metals. Coal.

6th Composition (p. 60).—Aqueous rocks and igneous rocks. The order in which the former are superposed.

7th Composition (p. 61).—Fossils to be found in the different strata.

8th Composition (pp. 58 and 67).—Movements of the ground. Central heat and the crust of the earth. Changes in the distribution of land and water.

PARTS IV. AND V.

PHYSICS AND CHEMISTRY.

PREFACE.

Before the English translation of the "First Steps in Scientific Knowledge" appeared, five hundred thousand copies of the original had been sold in France within three years. Immediately after the appearance of the first English edition a second was called for, and the American publishers feel confident that the success of the American edition will not be less than that of the foreign.

The American editor has made in the excellent translation of Madame Bert only such changes and additions as were necessary to Americanize the book, and adapt it to the requirements of public and private schools as well as to home instruction in this country.

The alterations in the Physics and Chemistry are confined to certain corrections and more elementary forms of expression, and do not extend to the subject-matter of the original.

TABLE OF CONTENTS.

PART IV.—PHYSICS.

PART V.—CHEMISTRY.

THE PHYSICAL SCIENCES.

IV.—PHYSICS.

1. We will to-day begin the study of the PHYSICAL SCIENCES. Under this name are comprised *Physics*, *Chemistry*, and *Physiology*. These sciences are very important, extremely interesting and curious, and at the same time very different from all that we have hitherto studied.

As in the pursuit of these sciences experimental investigation is frequently necessary, they are sometimes called EXPERIMENTAL SCIENCES.

2. **Observations and Experiments.**—The first thing I must explain is what is meant by the word experiment. See, here is a bit of wood. I throw it into the water. Thereby I learn that it floats, and the fact that it does so leads me naturally to the conclusion that the bit of wood must be lighter than water. I then fix weights to it and take note of the quantity I must add to make it sink and be as heavy as water. This is an *experiment*. Again, I put the wood in the fire; there you see it burns, gives off flame, smoke, and, if not allowed to be completely consumed, it leaves charcoal. This also is an *experiment*.

3. **Physical Experiments and Chemical Experiments.**—The chip of wood I threw into the water a little while ago, when taken out and dried, regained its first condition; nothing was changed in its composition. This is an example of a *physical experiment*. But now that it is burned to charcoal there are no means of restoring it to its original condition;

What is the character of physical experiments?

and yet it has not been destroyed, for were we to weigh the charcoal, the smoke, and something else I shall tell you about afterwards, we could find the exact weight of the bit of wood; but the nature of the wood is totally changed. We have this time made a *chemical experiment.*

Now let me see if you have perfectly understood what I have been telling you. There, I put some salt in this glass of water (Fig. 1). What will be the result?—"The salt will melt away."—Say, rather, it will *dissolve:* the expression is more correct. But, tell me, have I made a chemical or a physical experiment?—"A chemical experiment; for the salt has disappeared."—No: think again: the salt has not really

FIG. 1.—The salt has not disappeared in the water: it has only changed its appearance, for it can be found again by evaporating the water. (Physical experiment.)

FIG. 2.—Iron dissolved in sulphuric acid becomes another body, sulphate of iron, under the form of green crystals. (Chemical experiment.)

disappeared: *it has only changed its appearance.* The proof of this is that the water has the taste of salt; moreover, if we pour the contents of the glass into a plate, and put the plate on the stove, the water will evaporate, and when the evaporation is complete you will find upon the plate *crystals of salt,* just as they were before the experiment.

Now, here I show you a glass containing *oil of vitriol,* or, as CHEMISTS call it, *sulphuric acid,* into which I put, as you see, a few bits of iron wire or some nails (Fig. 2): these seem to dissolve, as the salt did in the water. Only you see that the liquid becomes green, instead of remaining colorless as it was. Then if you allow it to evaporate, as in the preceding experiment, you will find that there remain not bits of iron, but beautiful green CRYSTALS. In this case the sulphuric acid and the iron have both disappeared, and a *new body* has been formed, which, on account of its origin, chemists have called *sulphate of iron,* commonly known as *green vitriol.*

What is the character of chemical experiments?

To sum up what I have been telling you, I should say, then, that physical experiments MAKE NO LASTING CHANGE IN THE NATURE OF BODIES, while chemical experiments THOROUGHLY CHANGE THE BODIES, AND THEREBY GIVE RISE TO NEW SUBSTANCES.

I.—THE THREE STATES WHICH BODIES ASSUME.

4. Solid, Liquid, and Gaseous States.—You all know that there are SOLID as well as LIQUID bodies. A SOLID body is more or less hard, and has a definite shape of its own; a LIQUID has no shape of its own, and is a fluid; that is to say, *it will flow away* unless enclosed in a vessel made of a solid body.

Bodies also assume another state, of which it is more difficult to give you an accurate idea,—namely, the GASEOUS state. An experiment will give you much clearer ideas on the subject than a great many explanations. See, here is an empty glass. Holding it upside down, I plunge it slowly into this other larger vessel, which is almost full of water (Fig. 3). You see that the water does not fill the glass, and that above

FIG. 3.—The water rises only to A; the space B is filled up with air, which is a gas.

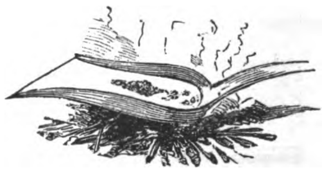

FIG. 4.—The zinc first melts, then changes into gas

the level of the water there is a space that appears empty. If you now incline the smaller glass to one side, a big bubble will escape, and the water will rise in the glass higher than

What are the three states which bodies assume? By what experiments can the existence of gas be easily proved?

before. What escaped in the bubble was air, or *gas which was* imprisoned under the glass, although, like the air that surrounds us, it is invisible.

Many bodies can successively assume the three states, SOLID, LIQUID, and GASEOUS. This is very evident in the case of water, which freezes into *ice* under the influence of cold, and evaporates in *steam* (or *gas*, which is the same thing) under the influence of heat. But this property is common to very many bodies, only under a different intensity of either cold or heat. Here is a bit of zinc that I have put on a shovel over the fire (Fig. 4): see, it rapidly becomes *liquid*, and were the heat strong enough it would soon disappear in *gaseous vapor*. Gases, on the contrary, are liquefied, and liquids are solidified, by *extreme cold. Very recently even air has been liquefied and solidified.*

5. Evaporation and Ebullition.—The change of a liquid into a gas can be brought about by two different processes. Here are a few drops of water on a plate (Fig. 5); in a short time they will have disappeared, and the plate will be dry: this is the result of *evaporation.*

So much for one process; let us now pass on to the other. Here is a pan-full of water which I have hung over the fire (Fig. 6). You can feel with your finger that the water

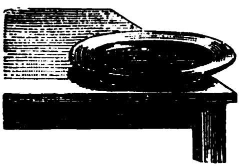

FIG. 5.—The water on the plate disappears *little by little:* evaporation.

FIG. 6.—The water in the pan bubbles up and gives off *clouds of steam:* ebullition.

Can all bodies assume the three states? Prove it, by taking water as an example. Now take some zinc. Give an example of the change of a liquid into a gas by evaporation.

is being heated; and you can also observe that the warmer it becomes the greater is the quantity of steam given off. At last the water begins to boil; that is to say, it bubbles up and gives off *clouds of steam:* if the heat be continued long enough, the water will all disappear, as a result of *ebullition*, which is a forcible change to the gaseous state, and takes place all through the liquid, instead of the slow and almost invisible process that we observed in the first case.

6. Distillation.—Now look at this. Above the boiling pan I hold a cold plate (Fig. 7). On coming in contact with the plate the steam *cools*, and, as you see, becomes *water*

FIG. 7.—The vapor *condenses*—that is to say, becomes *water* again—on coming in contact with the cold plate: distillation.

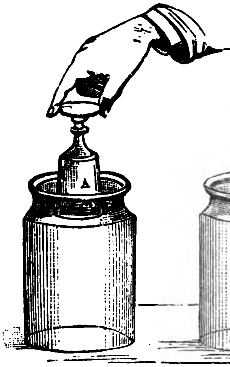

FIG. 8.—At the moment the glass touches the water it is full of air, A.

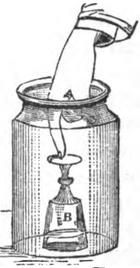

FIG. 9. — When the glass is at the bottom, the air is *compressed* at B.

again. The water thus obtained is *perfectly pure: it is called* DISTILLED WATER: *all its impurities have remained behind in the pan.* The proof that distillation purifies water is given by the fact that if you boil *salt water*, the product of the distillation of this salt water is *perfectly tasteless. Distilla-*

Give an example of the change of a liquid into a gas by ebullition. How is distilled water obtained? Prove that perfectly pure water may be obtained by distillation. What are the two operations of distillation?

tion is, then, a twofold operation. It first transforms liquids into vapors by heat; and then these vapors are re-liquefied by cooling.

7. Compressibility of Gases.—A little while ago, in order to prove to you the existence of gas, I made a simple experiment which teaches us something very curious about the properties peculiar to gases. Let us have recourse once more to our little glass, and invert it as before in a glass vessel full of water, pushing it straight and slowly to the very bottom. When the glass at first touched the surface of the water (Fig. 8) you know it was full of air, A; but now that I have pushed it down to the bottom (Fig. 9), the air evidently occupies less space, B.

This proves, then, that air can be easily COMPRESSED. On the other hand, when you withdraw the small glass from the water, the air it contains EXPANDS with equal facility.

8. Compressibility of Liquids and Solids.—All gases are, like atmospheric air, very easily compressed, or made to occupy less space, and as easily expanded, or made to occupy more space. But it is altogether different in the case of liquids and of solids. EXTRAORDINARY FORCE is required to compress *liquids*, and greater force still to compress *solids;* we may even say that they are almost INCOMPRESSIBLE. When people speak about compressed hay, for instance, you must not imagine that it is the hay itself that is compressed; that would be impossible: the stalks of hay are merely pressed more closely together as the air that was between them is expelled.

But the expansion and compression of liquids and solids, feats that defy the most powerful machinery, can be *easily accomplished by a little* HEAT *or a little* COLD.

What takes place when air is submitted to pressure? What happens to compressed air when the pressure is removed? Can solids and liquids be easily compressed? What takes place when hay is compressed? How can solids and liquids be easily compressed or expanded? What is the effect of heat on solids, liquids, and gases? What is the effect of cold?

II.—HEAT.

9. Expansion of Bodies.—When *heated*, solid, liquid, and gaseous bodies EXPAND; that is to say, they occupy a greater space than before. When cooled, they CONTRACT, or occupy less space.

Look at the wheelwright when he puts an iron tire around a wheel (Fig. 10): he makes the iron ring slightly smaller than the circumference of the wheel, then puts it into a large

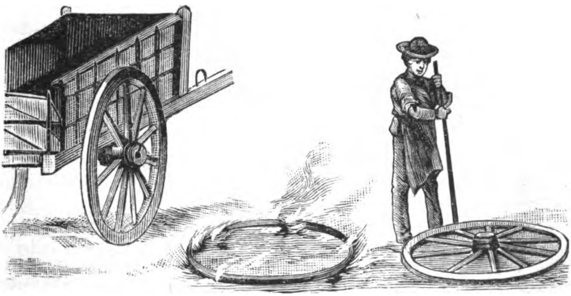

FIG. 10.—Cart-wheel with a band of iron around it. | Under the influence of heat the iron band enlarges, or *expands*. | In cooling, the band *contracts*, or becomes smaller.

fire. The heat causes the ring to expand, so as to allow the wheel to be placed within it; then it is cooled, and the iron contracts and causes the tire to fit so tightly to the wheel that there is no need for nails to fix it. This is a striking example of the expansion of *solid bodies by heat.*

Here now I show you a small bottle BA (Fig. 11) filled with colored water; through its cork passes a glass tube D, open at both ends, and the liquid rises in the tube to a certain height. I immerse the bottle in a vessel C containing very warm water; immediately you can see the colored liquid rise in the tube D by the effect of the *expansion* caused by heat.

Give an example showing the effect of heat on solid bodies. If a tube half full of water be heated, what will happen? If an empty tube closed at one end be plunged into water by its open extremity, and heated, what will happen?

Again, I put into a glass of water (Fig. 12) a tube AD closed at the upper end A, open at the lower, and full of air: the water of the glass rises in the tube to a certain height C,

FIG. 11.—The bottle BA is placed in warm water; immediately the water in the tube rises to D (expansion of liquids).

FIG. 12.—The tube being closed at A, the air in the interior *expands* under the influence of heat, and causes the water to sink from C to D (expansion of gas).

which I mark with a stroke of a pen. This done, I apply to the upper part of the tube the heat of an alcohol lamp. Immediately the water sinks in the tube to D: why so? Because the *expanded gas* takes up more space.

10. Change in Volume caused by Change of State.—Heat is necessary to cause a body to pass from a *solid* to a *liquid* state; and still more heat is required to make it pass from a *liquid* to a *gaseous* state.

As heat brings about EXPANSION, *a solid body will increase in volume by assuming the liquid state, and the volume will again increase in becoming gaseous.* Inversely, a liquefied gas occupies less space under its new form; and this is gen-

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What must be done to cause a solid body to pass into a liquid state? What to cause it to pass from a liquid state into a gaseous state? What is the consequence? What are the results of reversing the operation?

erally the case when a liquid is solidified. WATER, however, IS AN EXCEPTION to this general rule: *its volume increases in becoming solid, in becoming ice.* The force thus developed is enormous, for were a bombshell to be filled with water, the *expansion* which would be produced were the water to freeze would rend it to pieces. And this is why, when severe frost sets in, it is necessary to empty all tanks in which the water would be apt to freeze, else they would surely burst.

When stones are porous, and contain a certain quantity of water, this latter often freezes in cold weather, and they are then splintered and broken to pieces. From a similar cause, damp earth is raised up and crackled over during winter when there is no snow to cover it, just as the bark of trees is sometimes rent open.

11. Force of Expansion of Solids and Liquids.—From what I have already told you, you may easily conceive that the force developed by bodies when they expand under the influence of heat, or when they contract under the influence of cold, is something extraordinary. I shall endeavor to give you a still more accurate idea of this. You see this little iron rod I have in my hand; it is about one-third of an inch thick. If plunged into water at the freezing-point it would be ten inches long; in boiling water it would lengthen about the sixtieth part of an inch: this difference seems very trifling indeed. Well, trifling as it may be, if you wished to prevent this expansion you would have to put upon the end of the rod a weight of 7500 pounds: you would never have fancied that, I am sure. Therefore when metals are used in buildings *they must be arranged so as to have some working room,* otherwise the shortening and lengthening caused by the changes of temperature would disarrange the whole construction. So much for the force of cold and heat.

12. Temperature.—But what is cold, and what is heat? Ah! this is far from being easily understood. You must know, however, in the first place, that heat and cold are not

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Is it the same with water? What precautions ought to be taken with water-tanks when winter sets in? What is the effect of frost on stones that contain water? On the earth? On trees? What precaution against the expansion of metals ought to be taken in buildings?

two different things: to cool a thing is not to add cold, it is to take away heat. When a thing is warmer than our body, or, as we ought to say, when its *temperature* is higher than that of our body, we say it is *warm;* if its heat is less, or rather if its temperature is lower, than that of our body, we say it is *cold.*

13. Measures of Temperature.—We can easily distinguish, by feeling with the hand, not only a cold body from a warm one, but also different degrees of heat and cold. Here are two vessels in which I have made water boil: one was taken from the fire five minutes ago, the other about a quarter of an hour ago: dip your finger in both, you will feel that one is much hotter than the other. Here are two others taken off the fire, one an hour ago, the other two hours ago: they have lost so much heat that both are cold, but the latter seems colder than the former. It is, then, possible merely with one's hand to appreciate tolerably well, by comparison, the temperature of bodies.

But, as you can easily understand, this is not always sufficient. First, because one might be mistaken; further, how could the degree of heat be accurately expressed? This body is not so warm as that; but how much less? Is the body I touch at the present moment warmer or colder than the one I touched a week ago? I have certainly quite forgotten. And yet, were it necessary to know it, what could be done? Is it warmer to-day than it was this day last year? You do not remember; neither do I. Nevertheless, it is sometimes very useful that we should know such things.

14. Thermometers.—For this purpose instruments have been invented; and these instruments not only measure heat more accurately than the hand can do, but also give measures that can be kept in mind or noted down. The instruments I speak of are called THERMOMETERS (from two Greek words, *thermos*, heat, and *metron*, measure).

The first idea that presented itself was that heat might be measured by the *expansion* of bodies. Here is a bit of iron

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What name is given to instruments that are used for measuring the temperature of bodies?

wire: it will lengthen slightly if I heat it in my hand; if I plunge it into boiling water it will lengthen more; and still more if I put it in the fire. Were the extent of these three changes to be measured, we should have the exact indications of the degree of heat given by the hand, the boiling water, and the fire; but these variations in length are not sufficiently large to be easily measured, because the body acted upon is a solid.

Liquids expand to a much greater extent, and are, besides, more easily managed. They are, therefore, preferred for the construction of thermometers. It was a sort of thermometer we made a little while ago in our experiment with a glass tube full of liquid set in a bottle of water. But now we shall take a real one, which has been made for that purpose alone (Fig. 13). At the extremity of the tube of this real thermometer we find instead of a bottle, as we had in our experiment, a somewhat lengthened hollow bulb; instead of water it contains mercury, often called quicksilver. The tube is fixed upon a board with numbered divisions. As we have no use for these divisions, I shall separate the tube from the board.

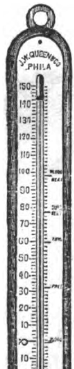

Fig. 13.—Thermometer with mercury, mounted on a scale.

We must remark, in the first place, the height of the mercury, and mark it A (Fig. 14). Now I have plunged the tube into a glass of cold water: the mercury sinks, and stops at a point which I mark B. I now take the bulb of the tube in my hand (Fig. 15): the mercury immediately rises again, and stops at a place which I mark C. James, put the bulb in your mouth (Fig. 16): the mercury still rises, and comes to a stand at the spot which I mark D. The distances between B and A, A and C, and C and D, indicate the differences of temperature that exist between the air, the glass of water, the palm of my hand, and James's mouth. The glass of water is colder, my hand and James's mouth are warmer.

George, in your turn, put the bulb of the thermometer in your mouth. See, the mercury rises, and stops short exactly at the same place as when it was in James's mouth: this proves that your mouth and his have the same tempera-

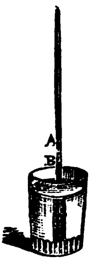

FIG. 14.—In cold water the mercury in the tube contracts, and sinks from A to B.

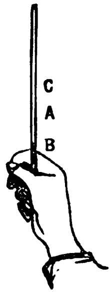

FIG. 15.—The heat of the hand causes the mercury to rise from B to C.

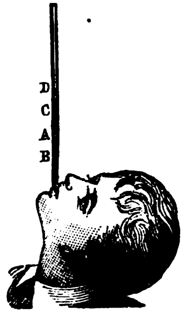

FIG. 16.—The heat of the mouth causes the mercury to rise from C to D.

ture. Now take the bulb in your hand; ah! the mercury falls lower than the mark C: that shows that your hand is colder than mine; but this is not surprising, as you have just taken it out of cold water.

15. Graduation of the Thermometer.—We are now in possession of an instrument which will enable us to *compare* the temperature of bodies. Only were an accident to happen to our instrument, all our observations would be lost. Of course we could easily make another; but there would be no means of comparing the new with the broken one, and all previous observations would be worthless.

This, then, shows the necessity of marking off all thermometers in the same manner, so as to be able to *compare* them with one another. For this purpose, as you can easily understand, it was impossible to take the temperature of things at random. I shall explain to you how this difficulty was overcome, and you will see that the plan,

although a very simple one, has been the cause of new discoveries.

Let us again take the thermometer we have separated from its scale. I have here a bit of ice, already half melted in the glass. Now I plunge the bulb of the thermometer into the water of the *melting ice* (Fig. 17). I see the mercury falls and stops at a certain place, A. Well, *all the time that the ice continues to melt the mercury will remain at that very spot.* This is one PRECISE spot easy to be found wherever a bit of ice is to be had. In the *centigrade thermometer*, used for *scientific purposes, this precise and invariable spot corresponding to* THE TEMPERATURE *of* MELTING ICE *or* FREEZING WATER *is called* ZERO. In the scale of *Fahrenheit's thermometer*, which is popularly used in the United States, this freezing-point is marked 32.

FIG. 17. — Thermometer plunged into *melting ice*. Temperature, 32°.

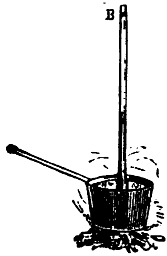

FIG. 18.—Thermometer immersed in *boiling water*. Temperature, 212°.

I now put the bulb of the thermometer into boiling water (Fig. 18): the mercury rises rapidly and stops at a certain place. I will mark this B. *All the time the water continues to boil the mercury will not move from this point.* This is another PRECISE and invariable spot, quite as easily found as the first. In the centigrade thermometer this place corresponding to the TEMPERATURE OF BOILING WATER is marked by the number 100. In the Fahrenheit scale the boiling-point is marked 212.

The distance between the freezing- and boiling-points is then divided into one hundred equal parts in the centigrade

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If I plunge into melting ice the bulb of a thermometer with mercury in it, what will happen? In thermometers for scientific purposes what is called *zero?* I place in boiling water the tube of a thermometer with mercury in it: what happens? In centigrade thermometers what does the mark 100 signify? Into how many parts is the tube divided between the 0 of melting ice and the 100 of boiling water?

scale, or one hundred and eighty in the Fahrenheit (Fig. 13). Each of these parts is called a DEGREE.

As our thermometer is already graduated, were I to register it in the air, in cold water, in the hollow of my hand, and in my mouth, we should find that the mercury would stop successively at certain numbers, say 15, 10, 25, 38. This shows us that the temperature of the air is 15 degrees (it is written thus, 15°), that of water 10°, that of my hand 25°, and that of my mouth 38° centigrade.

All these degrees *are above zero*. But in winter the column of mercury often falls *below* the zero point. Therefore equal divisions similar to those of the upper part are inscribed on the tube, marking the degrees *below the freezing-point.*

We have now finished with the thermometer. But I have still something to tell you about heat before leaving the subject.

16. Conduction.—Put your hand into this basin of water that has been upon my table since morning (Fig. 19). Is the water of the same temperature as the air?—"No: it is colder."—Try with the thermometer.—"The thermom-

Fig. 19. — Water appears to you colder than air because the water, being a *conductor* of heat, takes more of your own heat from you than the air does.

Fig. 20. — Charcoal, being a bad conductor of heat, does not burn my fingers, although the end is lighted, A.

eter marks 15° both in the air and in the water."—Then you see you were mistaken: the temperature of the basin of water is the same as that of the surrounding air, and yet the water seems colder. Put your hand on this marble slab, then on the table; the marble will seem to you colder than the wood, and yet it is not so. What can be the reason of this?

What name is given to each of these parts? What are the freezing- and boiling-points in the Fahrenheit thermometer? Why do water and marble appear colder than air and wood?

The reason is, that, the marble being a better conductor of heat than the wooden table, more heat is absorbed from your hand, and thus a greater sensation of cold is produced.

Here is a bit of charcoal, lighted at one end, A (Fig. 20). I can hold it in my hand, although my fingers are but a short distance from the burning part; yet it does not burn me in the least. Why? *Because charcoal is what is called a bad conductor of heat.* On the contrary, if I put into the fire one end of this iron rod (Fig. 21), the whole rod becomes hot, and, although it is ten inches long, I can scarcely keep my hand on the other end of it. And that is because *iron is a good conductor of heat*, for it allows heat to pass rapidly through its substance so as to reach my fingers.

To give you a striking example of the difference between a body that is a good conductor of heat and one that is a *non-conductor*, I will show you a very simple experiment. Here

Fig. 21. — I can scarcely hold my iron rod, it is so hot: iron is a *good conductor* of heat.

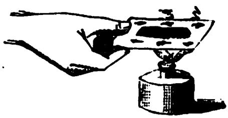

Fig. 22. — The card, being a *non-conductor* of heat, does not retain enough heat to set it on fire The tin, being a *good conductor*, absorbs all the heat and melts.

is a piece of card (Fig. 22) upon which I have flattened a little bit of tin foil. I hold the card above a gas-burner or over a small lamp. See, the tin paper melts, and yet the card does not take fire. *The tin, a good conductor, absorbs all the heat, while the card, a non-conductor, does not keep enough to take fire.*

METALS *are very good conductors; stones* are less good, and *wood* still less. AIR itself is a *non-conductor*. Therefore

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What name is given to this property in water and marble? Give another example of a bad conductor of heat. Give an example of a good conductor. What takes place in the card experiment? What do you know of the conductibility of metals, stones, and wood? Of air?

our clothes preserve us from cold for two reasons. In the first place, they are composed of fibres of cotton, hemp, or flax, or of threads of wool or silk, all of which are *non-conductors* of heat. Further, and above all, between the filaments of each tissue, and between the different parts of our clothing, there is a certain quantity of air: this air is very slowly heated; but when it is once heated it remains so, thus protecting us from outward cold.

Water being a better conductor of heat than air is, you can understand why you felt it cold when you plunged your hand therein. But when your hand was withdrawn from the water, did it get warm again immediately?—"No; *I think it felt colder than when in the water.*"—Ah! that also demands an explanation.

17. Heat absorbed in Evaporation.—I showed you a few minutes ago *that in boiling water, and during all the time it boils, the thermometer indicates the temperature of 100° centigrade;* in other words, the temperature remains constant. And yet we *added* heat, for the fire continued burning under the pan. What became of all this heat?

FIG. 23. — The vapor of the air is *condensed* on the bottle in drops of water.

This is not easily understood. All I can say upon the subject *is that this heat has been employed to make steam:* the proof of this is that if you prevent the formation of steam, by hermetically closing the pan, the temperature of the water rises beyond 100°. Now, do not forget this: *in order to produce vapor, in other words, to change a liquid into a gas,* HEAT IS NECESSARY. There was water on your hand a little while ago; and to dry that water, to allow it to become gas, heat was required. Where was this necessary heat to be found? *In your hand,* which in consequence was cooled.

And where does all this vapor go? Into the air? But it

Why do our clothes protect us from the cold? What is the temperature of boiling water in an uncovered saucepan? While the fire continues heating the saucepan, what becomes of the heat? Prove that heat is employed in making steam. Why is a sensation of cold felt when a wet hand is dried in the air?

is not visible. No, because it is quite transparent: nevertheless it exists. Here is a bottle just brought from a cool cellar (Fig. 23). The vapor of the air has *condensed* upon the bottle in minute drops of water. Where does this water come from? Not from the inside of the bottle, you are sure. No, from without, from *the air:* it was then in the state of vapor; and, as the bottle was colder than the surrounding air, the vapor became water by contact with the bottle, or, as we should say, it *condensed.* It is also *distilled* water. But as soon as the bottle is at the same temperature as the air of the room, the misty appearance will pass away: the water will have once more *evaporated.*

18. Power of Boiling Water.—I have just told you that if in heating water you prevent the formation of steam, the heat of the water rises beyond 100°. *The simplest way of preventing the formation of vapor is to heat the water in tightly-* CLOSED *vessels.* But the vessel must be very strong indeed, else it would soon be shivered in pieces. *For the vapor of boiling water has enormous force.* I have here a metal tube A (Fig. 24) which contains a little water, and which is well corked. I hold it with the tongs over the fire. The water of the tube soon reaches the boiling-point, and this is no sooner attained than the cork is violently expelled with a loud report.

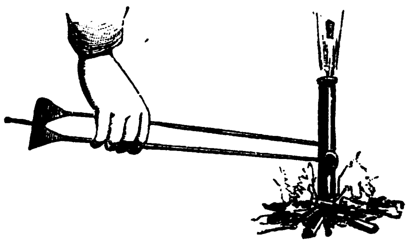

Fig. 24.—The force of the vapor imprisoned in the tube A causes the cork to fly out.

If, instead of corking the tube, I had shut it with a lid, closely fitted and firmly fixed, the temperature of the water would have increased, and the steam would have then acquired great force, and in a short time the tube would have been shivered to pieces.

Why does a bottle that has been brought from a cool cellar become covered with vapor? By what means is vapor or steam prevented from forming?

When water in a closed vessel reaches a temperature of about 250 degrees Fahrenheit, the pressure of the steam generated is equal to 30 pounds on the square inch.

It is upon this principle that *steam-engines* act. The water is made to boil in closed tubes, in which the steam produced acquires enormous force. This steam is then allowed to escape in a certain direction, and can, according to circumstances, lift heavy weights, or put into action great wheels, etc.

SUMMARY.—HEAT.

1. *Physical* experiments produce no alterations in the nature of bodies; *chemical* experiments totally change it, and give rise to new bodies.

2. **The Three States of Bodies** (p. 9).—There exist *solid* bodies, *liquid* bodies, and *gaseous* bodies.

A pebble is a solid body, water is a liquid body, air is a gaseous body.

3. Most bodies can successively pass through these three states. Thus, ice (solid) becomes water (liquid), then steam (gas).

Another example: Zinc, which is a solid metal, becomes *liquid* by melting over the fire, and is changed into a gaseous *vapor* if the fire is very strong.

4. **Evaporation, Ebullition, Distillation** (p. 10).—The rain that wets the highway is dried by *evaporation.*

5. The water that boils in the kettle sends forth vapor by *ebullition.* Ebullition is very rapid evaporation.

6. The water obtained by cooling steam is *distilled* water.

7. **Compression and Expansion** (p. 12).—When a body is forced to occupy less space than it did before, it is said to be *compressed.*

8. A body is said to *expand* when it occupies greater space than it did before.

9. *Gases* are very easily compressed and *expanded;* liquids and solids are almost *incompressible* by ordinary means.

10. **Expansion and Contraction** (p. 13).—What the most powerful machinery is unable to do, namely, to *compress* or *expand* water or iron, HEAT and COLD can accomplish with the utmost facility.

11. When a solid, liquid, or gaseous body is HEATED it EXPANDS.

12. When it is COOLED it CONTRACTS.

13. Gas occupies less space when it becomes liquid; and generally liquid occupies in like manner less space in becoming solid.

14. Water is an exception: its volume increases in becoming ICE. This is the reason why in winter pipes and reservoirs burst, and some stones break from the same cause.

15. **Thermometers** (p. 16).—One can measure the *temperature* of a body—that is to say, its degree of heat or of cold—with the help of a THERMOMETER.

What property does the steam of boiling water possess? Name an admirable invention that results from this property.

16. The invention of thermometers depends upon the property which liquids possess of *contracting* under the influence of *cold* and *expanding* under the influence of *heat.*

17. In the Fahrenheit thermometer the temperature of MELTING ICE is marked by 32.

18. The temperature of BOILING WATER in the same system is marked 212.

19. The interval is divided into 180 *divisions* called DEGREES.

20. Bodies Conductors of Heat and Bodies Non-conductors (p. 20).—Heat passes through the substance of bodies with greater or less facility.

21. Some, such as iron and other metals, conduct heat with great ease: these are called *good conductors.*

22. Others, such as air, wood, charcoal, conduct it with less facility: these are said to be *bad conductors.*

23. Water made to boil in tightly-closed vessels acquires a very high temperature, and gives rise to steam having very great power. This power is utilized in steam-engines.

III.—LIGHT.

19. Luminous Rays.—Where does *heat* come from?—"From the fire."—Yes, in a room; but outside?—"Ah! outside, from the sun."—Very well; but do the fire and the sun give heat only?—"No; they also give *light.*"—Exactly so. Well, as *heat always accompanies light*, it will be easier to see how heat proceeds in examining it with the help of light; for it is easier to follow out an observation with one's eye than with a thermometer. In the first place, light always moves in a straight line. See, in the school-room the sun is striking directly on the closed shutters (Fig. 25). Only, as there are holes in the shutters, you notice that from each hole there starts a luminous line in which dance myriads of tiny specks of dust. Place your hand in one of those lines, and you will have a sensation of warmth. This proves once more that *heat accompanies light.*

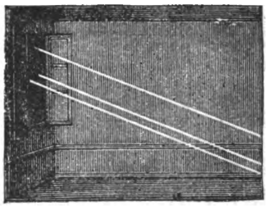

FIG. 25.—Light travels in a straight line.

How does light travel? What is it that always accompanies light?

20. Dark Room.—But this leads me to show you a very curious phenomenon. Go into the dark room and place a sheet of white card-board C (Fig. 26) on the line of yonder beam of light A*a*, B*b*, etc., that shines through the hole in the shutter. Look. All the objects outside are distinctly figured upon the pasteboard. Here is the pond beside the house, and the highway with a carriage on it; only on the card-board everything is seen upside down. Strange as this may appear, it is very easily explained.

From the top A of the poplar-tree, for instance, luminous rays start off in all directions; but only one can pass through the little hole so as to reach the card-board at the point *a*. From the foot of the tree another ray can penetrate and reach the point *b*. It is the same with all the points situated between *a* and *b*. So the poplar is seen figured head downward. The same thing happens, as you can easily understand, at all the other points of the landscape.

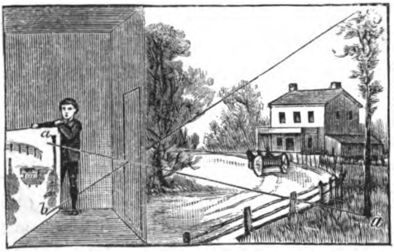

FIG. 26.—The objects outside are distinctly figured on the card-board C, only they are upside down.

21. Velocity of Light.—Light moves with extraordinary speed. It travels at the rate of 185,157 *miles in a second:* it would require but about the seventh part of a second to go all round the world, and it is only eight minutes in coming from the sun to the earth.

22. Reflection of Light.—Now be very attentive. I hold a small mirror so as to catch the sun's rays (Fig. 27). You can see on the walls of the school-room a luminous spot A make its appearance. If I move the mirror, the spot moves likewise.

This spot is formed by the sunlight falling upon the mirror

How fast does light travel?

and then starting off again: it is said to be **REFLECTED**. Let us go into the dark room (Fig. 28), and then catch upon the mirror the sunbeam that passes through the hole *r* of the

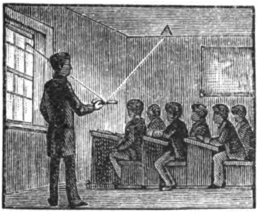

FIG. 27.—The light is sent back on the wall at A by the looking-glass (reflection).

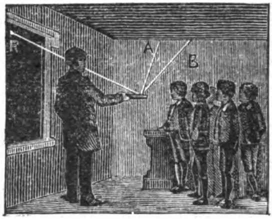

FIG. 28.—There is a direct relation between the direction of the ray received and the reflected ray A and B.

shutter. It is reflected, tracing a bright line in the dust of the air, and reaches the wall at A when I hold the mirror about straight; if I slightly incline the mirror, the reflected ray reaches the wall at B. There is, then, *a direct relation between the direction of the ray that falls on the mirror and that of the reflected ray*. We shall by and by learn to measure this relation.

This will explain to us how a mirror shows us our image when we stand in front of it; how our image (Fig. 29) seems to be placed just as far behind

FIG. 29.—Looking-glasses reflect objects (reflection).

FIG. 30.—The surface of the water reflects objects underneath as the mirror does.

I receive the sun's rays on a small looking-glass; what takes place? What name is given to this property of light falling in a slanting direction on the looking-glass?

the mirror as we are in front of it, so that savages never fail to seek behind the mirror the image they see in it; how it is also that the image is turned in the opposite way, so that the right hand seems to be the left, and *vice versa*. But, in order to understand all this properly, some notions of geometry are necessary: therefore we will wait until these are acquired before proceeding further in this direction.

The mirror I used a few minutes ago is a common tinned glass; but some mirrors are made of polished metal. Any smooth brilliant surface may serve as a mirror. Here is a glass of water (Fig. 30). See, I hold it a little above my eye, so as to look at the surface of the water from below. It appears to me like a plate of polished silver. Look at it yourselves: you may see all the surrounding objects reflected in it just as you would see them in a real mirror.

This will do for the present. We will now pass from this subject, namely, the *reflection of light*, to REFRACTION.

23. Refraction of Light.—*Refraction* is a word that signifies *breaking*. You will see that the word is perfectly suitable. I have here a glass of water, and into it I plunge

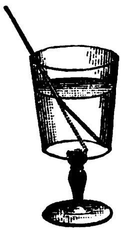

Fig. 31. — The bit of straw appears to be broken in the water (refraction).

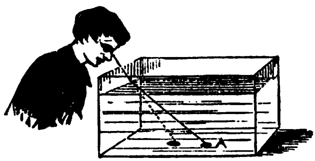

Fig. 32.—The luminous ray is broken on entering the water, and causes the penny to be seen at A in advance of the spot where it actually is (refraction).

obliquely a bit of straw (Fig. 31): the straw appears to you as if it were BROKEN, and seems to be more horizontally directed immediately on entering the water. You know very well that the straw is not broken, yet you can scarcely keep from thinking that it is so.

What happens if I plunge a bit of straw obliquely into a glass of water?

And again another experiment will lead us to a similar conclusion. I have prepared for the purpose (Fig. 32) a tin box, and put a penny in the bottom. Come here, and stand so as to be able to see only the farther edge of the penny. I now pour water into the box slowly and carefully, so as to avoid displacing the penny. Tell me what you see.—"I see the penny appear to rise and move forward towards A."—This happens because the rays of light from the penny are *deviated*, or seem to be *bent*, just like the bit of straw a little while ago.

This is what is called REFRACTION. It takes place every time a ray of light PASSES OBLIQUELY FROM A TRANSPARENT SUBSTANCE of one density—that is, thickness—to one of another density; the ray is bent in one direction when entering a denser substance, and in another when entering a rarer substance,—that is, one not so dense. Flat glass influences a ray of light in the same manner that water does.

I put flat upon this book a bit of thick glass (Fig. 33). You can see that the lines appear deviated as the straw did.

FIG. 33.—The lines of the book, in passing from the glass into the air, appear deviated (simple refraction).

FIG. 34.—The rays leaving the book deviate in passing—1, from the air into the glass; 2, from the glass into the air (two refractions).

If I hold the bit of glass at some distance from the book (Fig. 34), the deflection or bending of the lines will indicate two refractions. The first takes place when the rays of light that come from the book pass from the air into the glass; the second, when they repass from the glass into the air.

What name is given to this phenomenon? When is refraction produced? What name is given to a piece of glass convex on both sides?

24. Lens.—When a piece of glass is not flat on both sides, the deviations are much more complicated.

What name is given to this bit of glass A (Fig. 35) convex on both sides?—"It is a *magnifying-glass.*"—So it is; but the scientific name given to it is *lens.*

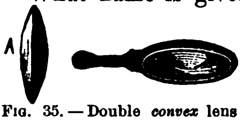

FIG. 35.—Double *convex* lens (rounded on both sides).

It is used, as its common name, magnifying-glass, indicates, to *magnify small objects.* Take this one in your hand, and look at the very fine print of this book. Well, what makes you look so astonished?—"Why, because I see nothing at all."—Have a little patience: you must neither put the lens close to your eye, nor your nose close to the book. Look as you generally do, only through the magnifying-glass, holding it at first close to the book. Now lift it slowly upward (Fig. 36), while you still keep looking through it. There now, the letters *seem larger.* Continue to remove the glass; they grow bigger still, and become quite distinct. If you still continue lifting the glass farther away, you will see them grow dim and finally disappear. So the proper distance must be found, *and the stronger the lens* the shorter this *distance is.* The lens you are using about doubles the size of things, and must be held at about an inch from the object looked at.

FIG. 36.—Double convex lenses magnify objects.

25. Compound Magnifying-Glasses and Microscopes.—When SEVERAL LENSES are arranged together according to certain rules, stronger magnifying power is attained, giving sometimes ten or twelve times the real size: this is what is called *a compound magnifying-glass.* Again, *microscopes* are made by still more complicated arrangements of lenses. MICROSCOPE (Fig. 37) comes from two Greek words, *micros,* small, and *skopeo,* to look at.

Great magnifying power may be obtained by a micro-

What are *magnifying-glasses* or *lenses* used for? What must be done in order clearly to distinguish an object with a lens?

scope. Things appear 100, 200, and even 1000 times larger than they really are. I see that this does not astonish you very much, because a quack at the fair declared that he could show things a million times larger than their real size. But this depends on the way of counting. When I say that my microscope magnifies ten times, I mean that an object the tenth of an inch long seems to be a whole inch long. The charlatans do not count in this way. As a thing is magnified not only in length, but in width and in thickness, they multiply three times; and so they would say that my magnifying-glass magnifies $10 \times 10 \times 10 = 1000$ times. Thus counted, the showman's million becomes simply 100. Only that would have made less fuss, and would have less amazed ignorant people.

FIG. 37.—The microscope magnifies still more.

Nothing is more instructive and interesting than to examine things with a magnifying-glass. I could not tell you all that you might see in examining *insects*, *flowers*, in fact everything around you, your own *skin*, your *clothes*, etc., with a magnifying-glass that need not cost more than half a dollar.

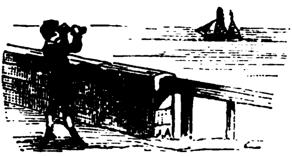

FIG. 38.—Telescopes magnify objects in the distance, and consequently make them appear near.

Had we time, how many astonishing and marvellous things might I not show with its help! *Thousands of living beings in a drop of stagnant water*, *millions of tiny red bodies in a drop of blood*, and I cannot tell what besides.

With the help of a microscope what can be discovered in a drop of stagnant water? In a drop of blood?

26. Telescopes and Spy-Glasses.—A sort of microscope for magnifying things at a distance, so as to make them look near, is made by *arranging different* lenses in another way. This is called a SPY-GLASS, or a TELESCOPE (Fig. 38). With its help we can study even the stars, and see in them many details entirely invisible to the naked eye.

27. Eye-Glasses, or Spectacles.—There is still another and well-known kind of magnifying-glass, namely, *eye-glasses*, or *spectacles:* these are small oval bits of glass which people having bad sight put before their eyes. I am obliged to wear them because I am old; here they are. You see they are simple *lenses* that magnify but slightly: take them in your hand, use them like a magnifying-glass, and see if you can read with them.

I see Henry shakes his head. Ah! I see why. I am not the only person in the school who wears glasses; James, although young, is obliged to use them, and Henry finds that James's glasses cannot be used as a magnifying-glass. He is quite right, too, and I will explain to you why.

You must know that there are not only *convex* lenses, but also *concave* ones (Fig. 39). Now, concave lenses, instead of magnifying things, lessen them; instead of making objects look nearer than they are, they make them appear farther off.

FIG. 39.
Double *concave* lens (hollow on both sides).

Come here beside me, James, and bring your book along with you, only take off your spectacles; I have put mine aside also. And you, Henry, who have good eyes, come and stand beside us. Let us try to read at the same time, each in a book with the same-sized print. Now that I have not the help of my spectacles, you see, I am obliged to hold my book at arm's length (Fig. 40) before I can distinctly discern the letters; James, on the contrary, puts his close under his nose; while Henry holds his at a reasonable distance, about ten inches from his eyes. This is because Henry has good sight, James has short sight,

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What name is given to a lens that is slightly rounded on both sides? What name is given to a lens that is a little hollowed on both sides? What is the effect produced by a *concave* lens? What kind of sight are those persons said to have who see near objects, but not such as are far off? Those who see far, but not near?

or *myopia*, and I have long sight. We will now put on our glasses again. Ah! that is right; we all three hold our books in the same manner (Fig. 41). Our bad sight is cured. I will give you the explanation of this fact when we study *Physiology*.

Fig. 40.—Henry has good sight, I am *long-sighted*, and James is *near-sighted*.

Fig. 41.—We have put on our spectacles: our bad sight is cured.

Now let us leave aside the lenses that *lessen*, and that are useful only to short-sighted persons, and return to *magnifying lenses*. Until now we have used them for looking directly at things, by holding them between our eye and the object we desired to see. We can use them also for another purpose.

28. Focus of a Lens.—Look! this time I hold my lens right in the sun (Fig. 42). Behind it I place a sheet of paper, towards which I gradually bring the lens. You see at a certain distance a *white spot* A *appears upon the paper;* this spot gets smaller as the lens comes nearer, until it becomes only a *speck* in size, but is excessively brilliant and luminous. And no wonder; *for all the sun's rays that fall upon the lens are brought together in this spot.* This spot is called the FOCUS of the lens. In order to use the lens as a magnifying-glass, *the object to be magnified must be placed between the focus and the lens.* Do not forget this.

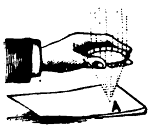

Fig. 42. — All the luminous rays are brought together at the point A, called the *focus*.

What happens when a lens is placed above a piece of paper so as to attract the sun's rays? What is that point called where all the sun's rays meet? When a lens is used as a magnifying-glass, where ought we to place the object we wish to magnify?

Come here and hold out your hand above the sheet of paper (Fig. 43); see, the focus shines on your skin. But why do you draw away your hand?—"Because I feel the bright spot to be *very hot.*"—Very well; that will help you to keep in mind *that* HEAT *always accompanies light, and that the heat-focus is at the same point as the light-focus.*

The larger the lens is, the greater is the quantity of sunlight it gathers together and concentrates, and the more luminous and hot is the focal point. With this little lens I

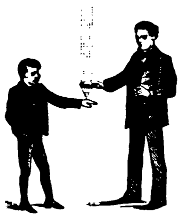

Fig. 43.—At the *focus* A, on your hand, all the rays of *light* are brought together.

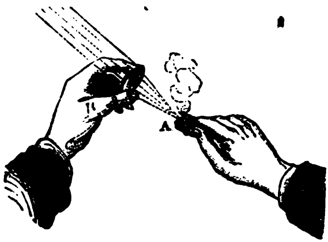

Fig. 44.—At the focus A of my little lens all the rays of heat are brought together, and light tinder.

can easily set fire to tinder (Fig. 44). But to obtain this result it is not necessary that the lens be of *glass;* all *transparent* bodies will answer the same purpose; ice, for instance, since it is a transparent body. Navigators at the North Pole have been able to kindle fire with the pale rays of the Arctic sun concentrated by a large lens hewed out of a block of ice. Great, of course, was the amazement of the Esquimaux at this sight, and equally great was the surprise of the sailors.

Colors.

We come now to a very important and most interesting experiment.

29. Dispersion of Light. Solar Spectrum.—Here is a

What is it that is called the *heat-focus* of a lens? What experiment can be made with a lens and some tinder? By what means can a fire be kindled with ice?

cut-glass bottle-stopper with six faces (Fig. 45). I turn it in the sunlight, above this sheet of paper. When in a certain position, it casts on the paper a *many-colored spot*. If you look attentively at this spot you will see that in the middle it is bright *green* and *yellow*, on the one side *red*, on the other *blue and violet*. You all recognize the colors of the RAINBOW. It is said they are SEVEN in number: these seven are, beginning with the violet side (which is the lowest in the rainbow), VIOLET, INDIGO, BLUE, GREEN, YELLOW, ORANGE, and RED.

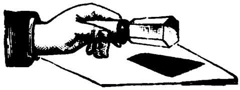

FIG. 45.—The block of cut glass divides the solar light into seven colors: *violet, indigo, blue, green, yellow, orange, red.* The combination of these colors is called a *spectrum.*

But in reality there are a great many shades running into one another and blending together, from the red to the violet, so that it is impossible to tell where one begins and another ends.

The term SOLAR SPECTRUM is applied to this combination of colors of the miniature rainbow that our stopper has given us; the way in which the light spreads itself out is called DISPERSION.

A spectrum is obtained when a ray of light passes through a transparent body, provided the surface through which the ray enters is not parallel to that by which it passes out.

This shows that *all the colors are contained in the sunlight, although it is apparently white* and *colorless.*

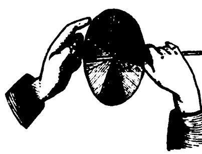

FIG. 46.—The *white* light is produced by the *union* of the seven colors of the spectrum.

30. Recomposition of White Light.—I shall now proceed to prove this to you by means of a very simple experiment. Here is a round bit of card-board, upon which I have painted all the colors of the rainbow (Fig. 46). The card-board has a little hole in the centre,

Into how many colors is the solar light divided? What are these seven colors? What name is given to all these colors taken together? What name is given to the phenomenon of a ray being divided into seven colors? How can a spectrum be obtained? What conclusion may we draw from the formation of a solar spectrum? What color does a card assume when painted with the seven colors of the spectrum and whirled round rapidly?

into which I introduce a rod. I then rapidly whirl the card round the rod as round an axle.

You see the colors disappear, and the card-board becomes almost white.

It is not even necessary to paint the *seven* principal colors on the card-board; *three* would be sufficient,—red, yellow, and blue. The reason of this is that the other colors, orange, green, and violet, can be produced by the blending of the three others, two by two. See, here is another bit of card-board, painted half *red*, half *blue;* if I make it whirl round like the first piece, it will appear VIOLET; and this other, which is half *red*, half *yellow*, will appear ORANGE; lastly, this one, which is half *yellow* and half *blue*, will seem GREEN.

31. The Color of Objects.—But what does it mean when we say that this card-board or anything else is white, and that green or red or black? It means that the white *card-board or any other white object reflects, that is, gives out, all the light it receives, and keeps back or absorbs nothing; blue or red absorbs all it receives except the blue or red part of the ray; black absorbs all and reflects nothing.* What is the reason of this? Ah! I am at a loss to explain it, so you must content yourselves with the mere knowledge of the fact.

In like manner, if water is colorless, wine red, ink black, it is because water lets the whole ray of light pass through it, while the red part alone passes through the wine, and the ink absorbs all.

There are, then, two sorts of colors, colors given by *reflection*, as is the case with the sheets of card-board, and colors given by *transparency*, as is the case with colored liquids or colored gases, or transparent solid bodies, like glass.

Certain bodies have not the same color when seen by reflection as when seen by transparency. This very thin sheet of beaten gold-leaf, for instance, looks quite *yellow* when the light shines upon it, yet if you look at it when placed between you and the light it will seem to be *green*. Such instances are, however, rare.

What color does a card half red, half blue, appear to be while whirling round? Half red, half yellow? Half yellow, half blue? What is meant when it is said that the color of an object is white? Or blue? Or red? Or black?

SUMMARY.—LIGHT.

1. Propagation and Rapidity (p. 25).—Light travels in *straight lines.*

2. It travels at the rate of 185,157 miles per second.

3. Reflection (p. 26).—When a luminous ray falls upon a mirror it is *reflected,* that is to say, THROWN BACK, according to a given angle, and projects a brilliant spot upon the wall. This phenomenon is called REFLECTION.

4. Refraction (p. 28).—A body partially immersed in water looks as if it were *broken:* this is the effect of the deviation of luminous rays. This phenomenon is called REFRACTION.

5. Refraction may be observed every time a luminous ray passes obliquely from one transparent body to another equally transparent, but of different density.

6. Lenses (p. 30).—A *lens* is a bit of glass which has one or both of its sides concave or convex: there are *convex* lenses, that enlarge objects, and *concave* (or *hollowed*) lenses, that lessen objects.

7. *Magnifying-glasses* cause things to look larger, and are made with a convex lens.

8. *Microscopes* are formed by a number of lenses arranged according to known rules in such a manner as greatly to magnify the dimensions of things quite near.

9. A *telescope* is formed by several lenses so arranged as to magnify distant objects.

10. *Spectacles,* when intended for near-sighted persons, are formed of concave or hollowed lenses; those destined for long-sighted persons are formed of convex lenses.

11. The rays of sunlight that fall upon a convex lens come together beyond the lens at a point called the FOCUS.

12. As heat always accompanies light, rays of heat are also concentrated at the luminous focus.

13. Dispersion, the Solar Spectrum (p. 34).—When a ray of light passes through a transparent body having two plane but not parallel faces, it spreads out, or *diffuses itself,* and produces a sort of *colored band,* in which the SEVEN COLORS of the rainbow may be recognized. This colored spot is known by the name of the *solar spectrum.*

14. The seven colors of the spectrum are arranged in the following order, beginning with the under part of the rainbow: *violet, indigo, blue, green, yellow, orange, red.*

15. These seven colors united form WHITE LIGHT.

16. *Colored bodies* possess the property of reflecting or allowing to pass through them only a part of the colors composing white light. Thus, a *blue* object absorbs six of the seven colors, and reflects the *blue.*

[At page 93 subjects of composition are given.]

IV.—SOUND.

We are able to feel heat by the whole surface of the skin, light by the eye, and sound by the ear. We already know whence come heat and light, how they move, and how they act. Let us now learn something about SOUND.

Sound is always produced by the shock of two bodies. If struck even lightly, some bodies produce sound: such as this wineglass, this metal lid, this tightened fiddle-string. Such objects are called *sonorous bodies.*

32. Sonorous Vibrations.—I have struck this wineglass with a rod: it gives a strong and clear sound. Put your finger on its edge (Fig. 47): what happens?—"The sound ceases."—Yes, but what did you feel with your finger? See, there I strike again.—"Ah! I feel *the glass tremble while it rings; when I stop the trembling the sound ceases.*"—It is said that the glass VIBRATES, and its *vibrations produce the sound.*

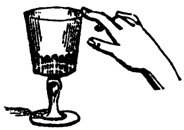

FIG. 47.—Sound can be produced by the vibrations of glass. When the vibrations are checked the sound ceases.

FIG. 48.—The vibrations of the tuning-fork are visible. If you stop them the instrument is silent.

Strike this tuning-fork (Fig. 48): its vibrations are quite visible; and when you check them the instrument becomes silent. So is it also with the wineglass; but you cannot perceive its vibrations.

Now, the glass and the tuning-fork are not in contact with our ear: how is it, then, that we can hear their vibrations?

We hear them because *they are transmitted to the air, which vibrates in its turn, and thus communicates vibrations to the interior of our ear.*

How is sound produced? What name is given to bodies that produce sound at the least shock? What is felt on putting the finger on a glass that has just been struck? What happens when you stop the vibrations of a glass? What name is given to this phenomenon? How is it that we hear the vibrations of a body that does not touch our ear?

If anything in my explanations puzzles or embarrasses you, you must tell me. Have you anything to say?

"Yes. When a gun is fired, it makes a great noise, yet nothing has been struck, nothing vibrates."—You are mistaken there: the *air vibrates.* The gunpowder on taking fire produces an enormous quantity of gas, which, having outlet only by the barrel of the gun, bursts out with extraordinary force. And this gas, when it violently strikes the air, sets it in *vibration:* thence the *sound.*

I will give you a proof that *sound is brought to us by air.* I will go into the yard, before the open window, and strike those two sticks gently on each other. You can all hear the sound? Now shut the window: the sound can be no longer heard. A thin pane of glass is sufficient to keep the sound from coming to you: it has prevented the vibrations of the air from reaching your ears.

But had the vibrations been strong enough, their energy would have reached the panes, and have caused them to vibrate also; they in their turn would have transmitted their vibrations to the school-room air, and so the sound from without would have reached your ears. Closed windows do not keep us from hearing many disagreeable noises, for example, that made almost a hundred yards off by our good friend the coppersmith as he hammers on his pots and pans. Besides, I am sure you have all heard the panes vibrate under the influence of a loud noise quite near.

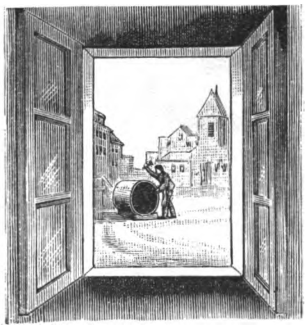

FIG. 49.—The sound is heard *after* the hammer has been seen to strike.

33. Rapidity of Sound.—*Sound does not travel very rapidly through air.* Open the window again. The boiler-maker, a hundred yards away, is making a great noise in mending the boiler of a steam-engine (Fig. 49). Look, and

listen attentively. Do you remark anything in particular?—"When I see the workman strike his boiler I hear nothing, and it is only when his hammer is as high as it can be that I hear the sound of the blow."—And yet, of course, it is when he strikes that he makes the noise. The sound you hear when the hammer is uplifted is the sound of the blow he struck an instant before.

Why this difference of time? *Because light travels with astounding rapidity, you see the movement that the workman makes at the moment he makes it, while, as sound travels much more slowly, it reaches you a little later.*

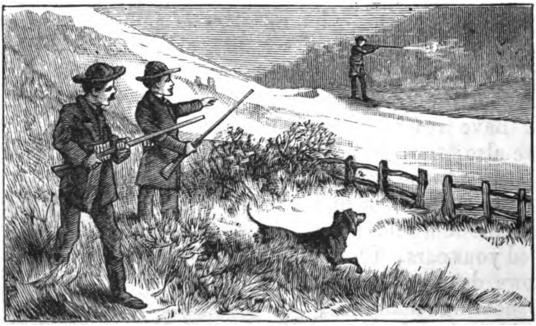

Fig. 50.—The smoke is seen *before* the report of the gun is heard.

The next time you have opportunity, watch a sportsman fire his gun (Fig. 50). *You will see the white cloud of smoke come out of the barrel some seconds before you hear the report;* and the greater the distance between the sportsman and you, the greater will be the time between the moment you see the smoke and the moment you hear the sound. It is by calculating this relation between time and distance that people are able to measure the rapidity with which sound passes through air.

The boiler-maker strikes a boiler in the distance: why do you see the movement of the arm before hearing the noise of the hammer?

It has been ascertained that sound travels through air at the rate of 1125 feet per second.

34. Transmission of Sound by Solids and by Liquids.— I have already told you that it is by *air* that sound is generally borne to us. But sonorous vibrations can be carried to us by *liquids* and even by *solid bodies*. Put your ear to the end of this long table (Fig. 51): although I touch the other end very gently, you can distinctly hear the sound.

You hear it even better than you would if the vibrations reached you through the air, *for vibrations are transmitted with greater rapidity and strength by solids and by liquids*

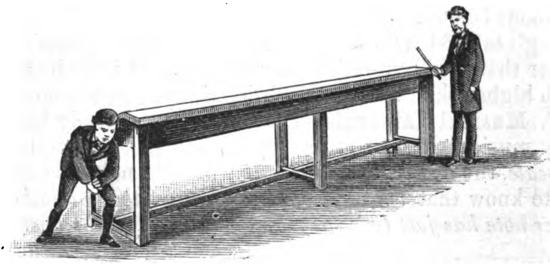

FIG. 51.—*Solids* transmit sonorous vibrations better than *air*.

than by air. Sound travels through wood ten times more rapidly, through iron fifteen times more rapidly, and through water four times more rapidly than through air.

35. Reflection of Sound.—*Sound is reflected back from a solid or a liquid body, just as light is*. It is for this reason that, under some peculiar conditions, a sound once emitted may be heard repeated once or oftener. This is called an *echo*. Echoes are generally to be heard when one is in front of a high wall or a large rock, or in a spacious empty room or vaulted chamber. If under such circumstances you speak in a loud tone, you first hear your own voice; the sound goes

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How fast does sound travel through the air? Is it through air only that these vibrations can be transmitted to us? Compare the rapidity of sounds transmitted to us through air with that of those which come through solids and liquids. Mention a property of sound analogous to one of light. When does an echo generally take place?

forward, strikes against the obstacle, and is thence reflected back and reaches your ear, so that you hear it again. This is a *simple* echo; but there are often *double* and *triple* echoes, etc. In the castle of Simonetta, near Milan, there is an echo that is said to repeat thirty-two times.

36. Ranges of Sound.—Sounds differ greatly from one another. There are *deep* or *grave* sounds, and *high* or *sharp* sounds; this difference is due to the number of vibrations in a second to which these sounds correspond. *The more numerous the vibrations are, the higher is the sound.*

The deepest or gravest tone that it is possible for us to hear has 32 vibrations per second; the highest, the shrillest, has about 70,000. Man's voice can scarcely go below a sound that gives 164 vibrations per second, nor woman's voice higher than 2088 vibrations per second; but you children go much higher than that in the shrill cries you sometimes utter.

37. Musical Intervals.—You may have already begun to study music. If so, you know your notes, and something of the *scale*, the *octave*, the *fifth*. It will then no doubt interest you to know that *when a note is an octave above another, the higher note has just twice as many vibrations as the lower one;* when a note is at the fifth, it has $\frac{3}{2}$ more.

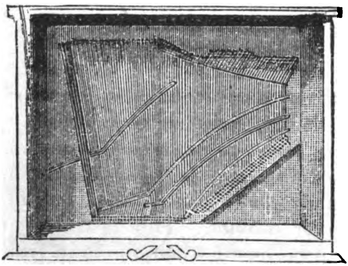

FIG. 52.—Interior of piano. The longer the string the deeper the sound; the shorter the string the shriller the sound.

We shall see this better with the help of our tuning-fork, which is tuned to the middle A of our voice: this A is produced by 806 vibrations per second. The C under it has 480 vibrations; the C above this, $480 \times 2 = 960$. The *sol* (the interval from C to G is a fifth) gives $480 \times \frac{3}{2} = 720$ vibrations.

38. Musical Instruments.—I must, however, mention

What results from these vibrations being more or less numerous? What may be observed when a note is an octave higher than another? By how many vibrations in a second is the middle A produced?

that instruments by which we obtain musical sounds are of several kinds.

First, there are STRINGED INSTRUMENTS, in which sound is produced either by *rubbing* with a bow on tight strings, like those of the fiddle or the violoncello, or by *striking* them with little hammers, like those of the piano (Fig. 52), or by *pulling* them sharply with the fingers, like those of the harp or the guitar.

The longer the string, the deeper the sound; the shorter the string, the shriller the sound. When a string gives a certain sound, if shortened to half its original length it will give just the octave above the first sound. Thus, when it is half the length, it must give double the number of vibrations.

But you must also know that it is not only the length of strings that determines sound. A difference in the thickness, or in the material of which they are made, or in the tightness of their stretching, gives to strings of equal length very different powers.

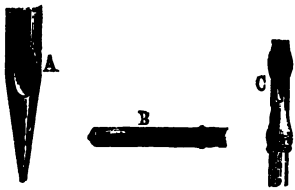

FIG. 53.—A, orifice of the pipe of an organ; B, of a flute; C, of a flageolet.

After stringed instruments come WIND INSTRUMENTS; these are of two kinds. In some, such as the pipe of an organ, the flute, and the flageolet (Fig. 53), the air, forcibly blown, strikes the edges of an orifice A, B, C, thus causing a vibration of the column of air contained in the pipe. In this case, also, it has been found that a pipe double the length of another emits a sound that has only half the number of vibrations given by the shorter one.

FIG. 54. — Reed of a clarionet.

In wind instruments that have *reeds*, such as the clarionet, the sharply-blown air strikes upon the reed A (Fig. 54) (a little blade placed in the mouth-piece of the instrument), and causes it to vibrate; thence vibrations are transmitted to the air contained

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In what category of instruments is the fiddle ranked? The piano? The guitar? What is the law of the vibration of cords? To what category of instruments belong the pipe of an organ, the flute, and the flageolet? The clarionet?

in the tube of the instrument. Such a reed may be made from an ordinary wheat-straw (Fig. 55). When a cornet, or any other brass instrument, is played, it is the lips that vi-

FIG. 55.—Reed made of wheat-straw.

brate in the same fashion as the reeds. In our larynx sound is produced in somewhat the same manner as in a cornet.

The *tuning-fork* must not be forgotten, either. Here is a cut representing one (Fig. 56). It is a curved rod of steel A, B, C, which is set in vibration on being struck by some hard body. Each tuning-fork gives but one note, the sound of which depends upon the dimensions of the instrument. The larger the tuning-fork the lower the sound it produces. Those most generally used give the A that has 806 vibrations per second.

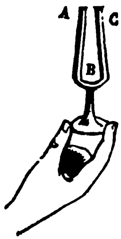

FIG. 56.—Tuning-fork. A, B, C, branch of steel which when set vibrating gives the A that has 806 vibrations in a second.

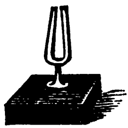

FIG. 57.—If I place the tuning-fork on a wooden box (*sounding-board*) the sound becomes stronger.

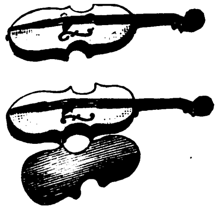

FIG. 58.—When the box is closed, the sound is strong; when the box is open, the sound is weak.

39. Intensifying Sounds.—Observe here a very important fact. If I make this tuning-fork vibrate, while I hold the foot of the instrument in my fingers, you can hardly hear the note it gives. If I put the instrument on the table, or, better

What is a tuning-fork? What note does the tuning-fork give?

still, on this empty box (Fig. 57), the sound is REINFORCED, or intensified, and is easily heard throughout the room. *The reason of this is that the air within the box vibrates in unison with the tuning-fork.*

The wooden case of the fiddle, as well as that of the piano, has the same effect. I have here an old fiddle, the body of which I have arranged so that I can open and shut it like a box (Fig. 58). When I shut the lid and play on the strings, the sound is strong and bold; when I open it, you can hear how much it is weakened. These arrangements which strengthen or reinforce sound are called *sounding-boards.*

SUMMARY.—SOUND.

1. **Vibrations** (p. 38).—SOUND is always produced by the shock of one body upon another.
2. This shock produces *vibrations,* which are transmitted to the air and thence to our ear.
3. **Velocity of Sound** (p. 39).—In air, sound travels at the rate of 1125 feet per second.
4. Sonorous vibrations can be transmitted to us by solids and by liquids better even than by air.
5. **Echo** (p. 41).—Sound can be REFLECTED back from a solid or a liquid body, just as light is reflected from a mirror.
6. This reflection of sound is called an ECHO.
7. **Low Tones and High Tones** (p. 42).—There exist *low,* or *grave* tones, and *high,* or *sharp* ones.
8. The greater the number of vibrations, the higher and more acute is the sound.
9. A sound is an OCTAVE higher than another when it gives *twice* the number of vibrations that the lower sound gives.
10. **Musical Instruments** (p. 43).—There are *stringed* instruments and *wind* instruments.
11. In stringed instruments, the *longer* the string is, the *lower* is the sound it emits; the *shorter* the string, the higher the sound.
12. Likewise in wind instruments, the longer the pipe is, the deeper and graver is the sound.
13. Sounds are strengthened by elastic plates of wood (as in the case of the piano, the fiddle, etc.).
14. **Diapason Tuning-fork** (p. 44).—The tuning-fork is generally constructed so as to give the A that has 806 vibrations per second.

[At page 94 subjects of composition are given.]

Why is the sound of a tuning-fork reinforced when the instrument is placed on a wooden box? What is it that in the piano and in the fiddle performs the office of a sounding-board?

V.—ELECTRICITY.

40. Sound, light, and heat have been known to man ever since his appearance on the globe. But it is scarcely two hundred years since he has had any knowledge of electricity, although lightning had many a time made him a witness of its effects.

41. Friction develops Electricity on the Surface of Wax and Glass.—Here is a stick of SEALING-WAX (Fig. 59). I present the end of it to little bits of paper: no effect is produced.

But if I rub it sharply upon my sleeve (Fig. 60), *the little bits of paper are instantly attracted, even from the distance of about a quarter of an inch* (Fig. 61).

If in this experiment a GLASS ROD is used instead of the stick of wax, *the same result is obtained.*

FIG. 59.—I place the stick of sealing-wax near the paper: no result.

FIG. 60.—I rub the sealing-wax,—

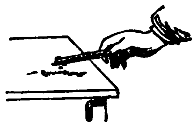

FIG. 61.—It attracts the paper.

Friction has, then, developed on the surface of the WAX, *and of the* GLASS, *a certain force*, capable of lifting little bits of paper: this force is ELECTRICITY. Ah! we are still far from the terrible lightning; but wait a little, we shall get to it.

42. The Two States of Electricity.—I shall now show you something more curious still. With a thread of silk I suspend from a sort of little stand a small ball of elder pith (Fig. 62). I briskly rub the *stick of sealing-wax* and then touch with it the ball of pith. *The pith ball is strongly attracted*, just as the bits of paper were, but *no sooner has the*

What happens when little bits of paper are placed near a stick of sealing-wax that has been previously rubbed? What name has been given to the force developed on the surface of the wax and the glass? What happens when a ball of elder pith is placed near a stick of sealing-wax that has been rubbed?

pith ball come in contact with the stick of wax than it is repelled to the point A. You see I can drive it away in any direction, if I pursue it with the wax.

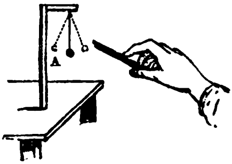

FIG. 62.—The little ball of elder pith is repelled as soon as it touches the wax A that has been rubbed.

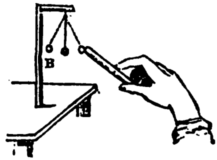

FIG. 63.—The elder-pith ball that fled from the wax is attracted by the glass rod, but as soon as the contact has taken place it is again repelled to B.

I then immediately take up my RUBBED GLASS ROD (Fig. 63), and put it in the place of the wax. *The pith ball that was repelled by the wax is attracted towards the glass rod; but in a short time it is again repelled*, and can be attracted again only by the WAX.

This experiment would lead to the belief that there exist two kinds of electricity, *one given by glass and the other given by wax.*

For this cause the name of VITREOUS ELECTRICITY has been given to the former, and RESINOUS ELECTRICITY to the latter.

They are also called, for reasons too difficult for you to understand as yet, NEGATIVE electricity for the resinous, and POSITIVE electricity for the vitreous.

All bodies thus emit electricity when rubbed, sometimes *negative*, sometimes *positive;* but its existence is not always so manifest as when glass or wax is acted upon.

43. Attraction and Repulsion.—Here now is a thick plate of *resin* upon a wooden support (Fig. 64). I rub it for a good while with a bit of woollen stuff. It then not only attracts light bodies, but also, every time my finger (Fig. 65)

What happens when a rubbed glass rod is placed near a small ball that was repelled by the wax? What seems to be shown by this experiment? What name is given to the electricity of wax? To the electricity of glass? What other names are used instead of *resinous* and *vitreous?*

approaches it, *it gives off little sparks that spring from it with a slight crackling noise.* This is real lightning in miniature: the spark is the *lightning*, the little noise the *thunder*.

Suppose that, instead of the little ball of pith I hung on the stand, I had in its place put a ball of *resin* carefully

FIG. 64.—I rub the resin with a piece of woollen cloth.

FIG. 65.—I place my finger near it, and I obtain little sparks, and a slight crackling noise.

rubbed. If the RESIN was placed near the ball, *the latter, instead of being attracted, would be repelled.*

If, on the contrary, *I held near it the large* GLASS ROD, the *ball of resin would be attracted by it.*

Now, if a *glass* bead were hung on the stand, it would be attracted by the resin, and would fly from the glass rod.

From these experiments the two following laws have been deduced:

1. *Two bodies charged with similar kinds of electricity repel each other.*

2. *Two bodies charged with different kinds of electricity attract each other.*

44. Conductors and Non-Conductors or Insulators.—See, with this stick of sulphur, after friction, I can also lift up bits of paper. In dry weather you may even draw electricity from your own hair, by the friction of the comb. Cats also, I may say especially, emit electricity, and their fur

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What happens when a large piece of resin, already rubbed, is placed near a small piece that has also been rubbed? What would happen if instead of the large piece of resin I were to place a small piece near a stick of rubbed sealing-wax? What would happen if the little piece of resin were replaced by a bit of glass? What laws may be deduced from these experiments?

stands on end when stroked, even gently (Fig. 66), when the weather is dry or frosty; if this be done in the dark, quantities of little sparks can be seen to spring out from under one's hand with a slight rustling noise.

But things do not work in like manner if I take an IRON ROD. I *may rub as long as I like, I can produce no manifestation of the presence of electricity.* If, before beginning to rub it, however, I wrap a piece of SILK several times around the end by which I hold it (Fig. 67), I can see the rod give some signs of electricity; that is to say, I can lift with it some small bits of paper. What does this indicate? This indicates that before I wrapped the silk round the iron *the electricity as soon as it was produced passed through the iron into my body and thence into the ground;* while at present, the rod being wrapped in silk, the electricity remains on the iron. But why was silk necessary to obtain this result? That is what I shall now explain to you by an experiment.

FIG. 66.—When cats are rubbed in dry weather they give out electric sparks.

FIG. 67.—If I wrap a piece of silk round the iron, it attracts the little pieces of paper.

I shall operate this time with a stick of wax that has not yet been used, and which you see cannot as yet attract anything. Very carefully and gently I rub the extremity on my sleeve,—the extremity alone (Fig. 68). You see (Fig. 69) it attracts bits of paper and other light bodies; yet at a very short distance from the end A no effect whatever is obtained.

Thus electricity has occurred only where friction had developed it, and has not spread over the remainder of the wax. For this reason wax is said to be a NON-CONDUCTOR of electricity. We have already made acquaintance with this term when speaking about heat.

I rub an iron rod and keep it in my hand: by doing so, shall I be able to attract the little bits of paper? If I wrap some folds of silk round the part of the rod that I hold, what then? What does that imply? In what way does electricity affect the wax? By what word do we express this quality of the wax? How does electricity affect an iron rod? By what word do we express this property of iron? Explain, now, why the bar of rubbed iron does not attract the pieces of paper.

On the contrary, when I produced electricity by rubbing the iron rod, *the electricity immediately spread itself over all the surface*, for iron is a CONDUCTOR of electricity. Now, the human body is also a conductor, although less so than iron; so is also the ground. Therefore, no sooner was electricity produced in the rubbed part of the iron rod than it *passed into my hand, thence to my body, and finally into the ground.*

As for the silk, it is a non-conductor. *So, in wrapping the silk around the iron, I kept the electricity* on the iron, and by dint of patient rubbing produced enough to allow the rod to give manifest signs of its existence.

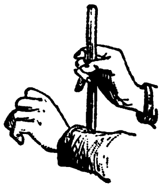

Fig. 68.—I rub the *extremity* of a stick of sealing-wax on my sleeve.

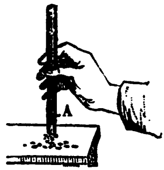

Fig. 69.—The extremity alone of my stick of sealing-wax attracts the bits of paper. There is no effect at A. The wax is a *non-conductor*.

Thus keeping in the electricity produced is called INSULATING *a body*. People use for this purpose silk, glass, resin, wax, porcelain, india-rubber, all of which are non-conductors. Woollen stuffs, dry leather, dry wood, are not good conductors either. On the contrary, METALS, water, and wet bodies, such as live plants, animals, and wet ground, are good conductors of electricity.

45. Different Methods of obtaining Electricity.—Electricity can be produced, first, by *friction;* secondly, by bringing an unelectrified body into actual contact with an electrified one; thirdly, by bringing an electrified body near to an unelectrified one without allowing the two to touch.

Thus we can get electricity, first, by *friction*, and under proper conditions; secondly, by *contact;* thirdly, by *induction*.

Explain why the bar of iron wrapped up in folds of silk attracts them. How do we express the action of keeping in the electricity produced?

1. When a body is rubbed it becomes charged with a certain quantity of electricity, which varies according to the nature of the body, *positive* in the case of glass, *negative* in the case of resin.

2. When a body is touched by another body previously electrified, the former becomes charged with electricity of *similar nature.* In the experiment with the pith ball hung by a silk thread, the ball attracted by the wax became charged with negative electricity (that of the resin); but as soon as there was contact it was immediately repelled, because electricities of similar nature repel each other.

3. *Electrical induction.* Suppose you have a ball (Fig. 70) charged with positive electricity. If you put this ball near another body, B, standing on an insulating foot, the body B divides itself as it were into two halves: that next to the ball C becomes charged with negative electricity; the other, D, with positive electricity. Hence this body, if movable, will be attracted towards the electrified body, because electricities of different natures are mutually attracted. This action at a distance is called INDUCTION.

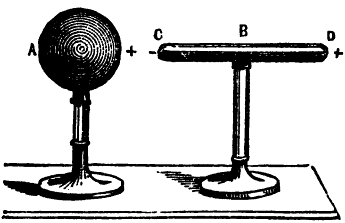

FIG. 70.—Electrical induction. The vicinity of the ball A, charged with positive electricity, induces into C negative electricity, and at D positive electricity.

46. Power of Points.—When a body capable of conducting electricity is electrified, if it be perfectly round (Fig. 71) *the electricity will spread equally over all its surface.* If it be egg-shaped (Fig. 72) *the electricity will collect especially at the two ends.* If we suppose the egg-shaped body capable of being lengthened out as a bit of putty can be, *all the electricity will collect at the two points.* Were I to taper to a point one of the ends (Fig. 73), leaving the other round, *all the electricity would go to the point;* the body would be unable to re-

What are the different modes of electrifying a body?

tain any, all would run out at the point. This is what is called the POWER OF POINTS. It consists, you see, in this, *that a body*

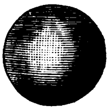

FIG. 71. — Electricity is spread all over the surface in a ball.

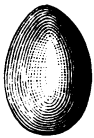

FIG. 72.—In an egg-shaped body electricity will collect especially at the two ends.

FIG. 73. — In a body terminating in a point all the electricity escapes by that point.

charged with electricity discharges itself rapidly if it is tapered off, or merely if a pointed body is stuck in it or applied to it. Of course the body must be a conductor of electricity, else the electricity would quietly remain where it was developed, without being able to reach the point.

FIG. 74. — Electricity glides gently towards the points of steeples or tall trees, and from them into the air, and into a cloud.

It is *this power of points that allows* LIGHTNING CONDUCTORS *to be of any use; it is also this power that causes the lightning to be attracted especially to steeples and tall trees, such as poplars.* We must examine further into this.

47. A Lightning-Conductor.—We have already seen that when two bodies are charged, one with negative electricity, the other with positive, they are attracted together. When

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In what consists the power of points?

they come in contact with each other, or even when they come pretty close to each other, a SPARK passes between them, and their electricity *disappears:* they are said to be *discharged* (*neutralized* would be a better expression). More than this, if the electrified bodies were tapered to POINTS the discharge *would take place with so much ease that it would not even produce sparks.*

Thus, when a cloud charged with negative electricity approaches the earth (Fig. 74), *it electrifies by induction the earth, whose positive electricity*, as I explained to you a little time ago, then accumulates upon all pointed objects. Then, if the cloud is not too near, or if it is not too strongly charged, or, again, if a shower has wet all those pointed objects and thus made them better conductors than usual, the electricity will *glide gently towards* the points and from them into the air and the cloud, which will thus be neutralized.

FIG. 75.—If a thunderbolt falls, it follows in preference the rod AB and is lost in the earth C.

But if the cloud contains a great quantity of electricity, or if the electricity of the earth cannot find the requisite number of pointed bodies to allow it to pass away with sufficient rapidity, *all of a sudden a spark, in this case a* FLASH OF LIGHTNING, *springs forth, sometimes from the point to the cloud, sometimes from the cloud to the point*, as the case may be. This flash is what is vulgarly called the THUNDERBOLT, which strikes in preference, as you know, trees and spires, especially when they have but few tall objects around them.

"But——" —Well, what do you wish to ask?—"But then, if you put a lightning-conductor on the steeple (Fig. 75), as

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What happens when a cloud charged with negative electricity approaches the earth? How does electricity affect the cloud if it is not too heavily charged? What happens if the cloud contains a great deal of electricity? What name is given to this spark?

has been done here, there will be no escape possible, and the lightning cannot fail to fall on that long sharp rod."—Quite right. But do not be afraid. Have you ever looked closely at the lightning-conductor of the church steeple? Is there nothing besides the iron point?—"Oh, yes; *there is a long iron rod, that runs down all along the building.*"—And where does this rod finish off?—"I have heard that it passes down into a well, but I do not know if that is true, or why it should be so."—It is quite true, and I will tell you why it is so.

When the cloud passes over the church, the water of the well and the iron rod of the lightning-conductor will always be in better condition to conduct electricity than any other part of the edifice, although it may be wet with the rain. The result of this is that the electricity of the earth will always choose the easiest path towards the cloud. And if a flash does spring forth, it will, in *falling*, as people call it, take the road that offers least resistance. Electricity is lazy, or, at any rate, prefers avoiding difficulties to overcoming them. This is the reason why the lightning-conductor will either discharge the electricity of the cloud slowly and without flashes of lightning, or, if there be a flash of lightning, the consequences will be borne by the conductor itself,—that is to say, the point, the rod, and the well,—so that the church will be preserved.

FIG. 76.—The discharge most frequently takes place between two clouds.

48. Two Kinds of Lightning.—"Please, *does lightning fall somewhere on the earth at every discharge of electricity from the clouds?*"—No. There are flashes that take place *between the earth and the thunder-cloud, and it is in such cases*

What happens if a cloud charged with electricity passes over a building that has a lightning-conductor? Name one sort of lightning.

that things on the earth are struck. Fortunately, however, in most cases lightning flashes *from one cloud to another*, one cloud being charged with positive and the other with negative electricity (Fig. 76): these clouds discharge themselves on coming near each other. Lightning is accompanied by a great noise, called *thunder*, produced by the displacement of air during the passage of the flash. This noise is prolonged by *echoes* rolling from cloud to cloud. The flashes that pass between the *earth* and a *cloud* produce only a sharp, short thunder-clap.

A certain interval of time, of greater or less duration, passes between the moment when the lightning is seen and that at which the thunder is heard. Can any of you explain to me why?—"The lightning is seen as soon as it is produced, *because light travels very rapidly*."—Very well; and sound? "Sound *travels only* 1125 *feet in a second*, and is much longer on the way."—Very good; and the knowledge of this fact affords a ready means for measuring the distance at which the lightning has been produced. *Count the seconds between the time you see the lightning and the time you hear the thunder: the distance which separates you from the place of disturbance is as many times* 1125 *feet as you have counted seconds.*

Production of Electricity.

49. And now let us return to the means employed for producing electricity. You can easily understand that it is impossible to obtain considerable quantities of electricity by merely rubbing a stick of sealing-wax with a bit of cloth in one's hand. The quantity thus developed is of no other use than to afford a little scientific amusement.

Electricity is produced on a large scale by two kinds of instruments,—namely, *electric machines and electric batteries.*

What are the consequences of this kind of lightning? What is the second sort of lightning? By what is this lightning accompanied? Why does this noise produce prolonged rollings? Why do we see lightning as soon as it is produced? Why does an interval of time pass between the lightning and the thunder? How can we measure the distance that separates us from the point at which lightning is produced? By the help of what instruments is electricity produced?

50. Electric Machines.—Electric machines (Fig. 77) *generally produce electricity by friction upon glass.* They are frequently composed of a plate of glass A revolving between two pairs of cushions CC′, DD′, that press on each side of the glass and rub on it as it turns. The electricity, which

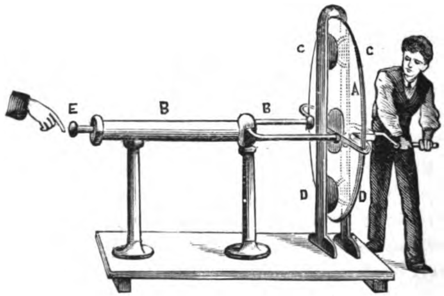

Fig. 77.—The rubbing of the glass wheel A between the cushions CC′, DD′, produces positive electricity, which accumulates at B.

is positive in this case, accumulates upon the metallic parts of the machine, so that when a large machine of this description is employed, sparks strong enough to knock down a man may be obtained: these sparks are sometimes about half a yard long.

51. Electric Batteries are of a totally different nature, and work upon quite another principle. You must learn that *whenever a chemical change, or, to use a more appropriate expression, a chemical reaction, takes place,* ELECTRICITY IS DEVELOPED. Thus, when, in the course of our first lesson on physics, we made sulphate of iron with some sulphuric acid and some iron, a certain quantity of electricity was produced; only, as we paid no heed to it, it was lost.

In electric batteries things are arranged so as to gather in or condense this electricity. Peculiar arrangements are adopted according to the chemical reaction chosen.

How do electric machines generally produce electricity? Upon what principle do electric batteries work?

In order to give you a pretty accurate idea of these batteries, I will make a very simple one before you. This battery, which I am going to make for your instruction, is called a *pile* (Fig. 78), and is similar to the earliest pile invented by the celebrated Volta. See, I pile up *copper pennies*, *disks of zinc*, *and disks of cloth*, all of similar size, arranging them as follows: a copper penny, cloth, and zinc; then another penny, and so on. When about ten of each have thus been piled up, I tie up the whole, dip it in some strong vinegar for a few moments, then wipe it and lay it on a plate. This done, two brass wires are fastened, one beneath and one above; one in contact with the *zinc*, the other with the *copper*. The acid of the vinegar attacks the zinc: a *chemical reaction is thereby produced.* The wire A that touches the copper will give positive electricity, while the wire B in contact with the zinc will give negative electricity. If I fasten together the two wires, or poles, as they are called, an ELECTRIC CURRENT will be produced,—very weak, of course, but still capable of showing itself.

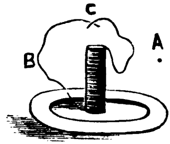

FIG. 78.—Electric pile. The wire A touching the copper gives positive electricity. The wire B touching the zinc gives negative electricity. C, the union of these two poles, producing the electric current.

52. Effects of the Electric Current.—I will now show you several proofs of the existence of this current.

FIRST PROOF.—Come here, and hold out the tip of your tongue (Fig. 79). There, I have placed the end of the wires on it: do you feel anything?—"Yes, a saltish taste."—Anything else?—"Ah! a sort of shaking in my tongue."—That is *caused by the passage of the current.* If instead of this weak little pile I employed a strong one, you would be unable to bear it on your tongue. Be-

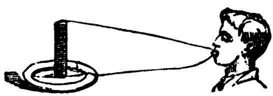

FIG. 79.—You feel a slight trembling of your tongue (physiological effect).

What is there in the battery we have just constructed that allows the electricity to escape? What sort of electricity comes from the wire A that touches the copper? What sort of electricity comes from the wire B that touches the zinc? What will happen if I unite these two wires? Mention a physiological effect produced on the tongue by the electric current.

tween your fingers, even, it would feel painful, and would give you violent shocks.

SECOND PROOF.—Here is a MARINER'S COMPASS (Fig. 80), composed, as you all know, of a needle set on a pivot, and the

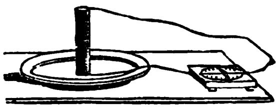

FIG. 80.—The needle of the mariner's compass puts itself across the wires of the pile (physical effect).

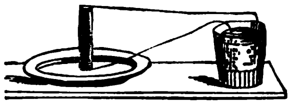

FIG. 81.—The water is decomposed into gas (oxygen and hydrogen) by the electric current (chemical effect).

needle *points to the* NORTH. I lay the united wires of the pile upon the compass in such a manner that they shall be in the same direction as the needle. Immediately *the needle turns and places itself in a direction crossing* the wires of the pile.

THIRD PROOF.—This time it is a glass of salt water (Fig. 81) that will show us the existence of the current. The two ends of the wires are immersed in the water at some distance from each other. Examine very closely, and you see that after a few moments little bubbles form at the end of each wire; they disengage themselves and rise to the surface. *These bubbles are the result of the decomposition of the water, produced by the action of the electric current*, as we shall see hereafter.

FIG. 82.—A little spark appears at each union and separation of the two wires.

FOURTH PROOF.—Lastly, let us carry our pile into the dark closet (Fig. 82), and shut everything carefully so as to be in complete darkness. I unite and separate several times the two

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Mention a physical effect produced by the electric current on the needle of the mariner's compass. Mention a chemical effect produced on water by the electric current.

poles of the pile. You can see at each contact *a small, very small, spark appear.*

And so we have obtained with our rough apparatus all the effects that strong electric machines give: 1. Action upon the human body, or *physiological effect;* 2. Action upon the magnetic needle, and the production of sparks giving light and heat, or *physical effect;* 3. The decomposition of water, or *chemical effect.*

But with large batteries or piles very extraordinary effects are obtained. A single shock is capable of throwing the strongest man into convulsions, or even killing him. When the sparks are made to pass between two points of carbon they produce the marvellous and splendid *electric light*, which is now used to light up our great cities. By the aid of electricity, various substances can be decomposed and metals may be deposited upon other bodies, as in gilding or silvering. And how many other marvels might I mention! but the list would be too long. Among the more useful applications are the *electric telegraph*, which carries news all around the world by means of a wire along which electricity runs with a fleetness equal to that of light; the *telephone*, which carries to a distance and reproduces the human voice, so that one may by its aid converse with and recognize the voices of persons in far-distant cities; the *microphone* also, which amplifies sound so as to render audible what was imperceptible, to such an extent that a fly walking over a sheet of paper makes as much noise as a horse prancing on a sonorous floor. Ah! it would take a lifetime to study the half of all these marvels.

SUMMARY.—ELECTRICITY.

1. **Positive Electricity, Negative Electricity** (p. 46).—***Friction*** develops on the surface of wax and of glass a certain force called ELECTRICITY.

2. Electricity obtained from wax is called NEGATIVE electricity.

3. Electricity obtained from glass is called POSITIVE electricity.

Mention a second physical effect produced by the union and separation of the two poles of the battery. What effect is produced by a strong battery upon a man? Name two applications of electricity to industry. Tell me of the electric telegraph. Of the telephone. Of the microphone.

4. Bodies charged with *positive* electricity REPEL those charged with *positive* electricity.

5. Bodies charged with *negative* electricity REPEL those charged with *negative* electricity.

6. On the contrary, bodies charged with *positive* electricity ATTRACT bodies charged with *negative* electricity.

7. Hence the two following laws:

1. *Bodies charged with similar kinds of electricity repel each other.*
2. *Bodies charged with electricity of opposite kinds attract each other.*

8. Bodies that are Good Conductors, Bodies that are Bad Conductors (p. 48).—If instead of rubbing *wax* or *glass* I rub an iron rod, the electricity developed by the friction spreads itself over the rod, passes through my body, and disappears in the soil.

9. In the case of the wax and the glass it is the contrary: the electricity *remains* just where the friction developed it.

10. It is said, for this reason, that iron, the human body, the earth, and water are GOOD CONDUCTORS of electricity.

11. Wax, glass, and silk are BAD CONDUCTORS.

12. In order to obtain any manifestation of the presence of electricity in the rod, I am obliged to wrap around it several folds of silk.

13. This process of thus keeping in electricity by means of a body which is a non-conductor is called INSULATION.

14. Electric Sparks (p. 49).—When one holds his finger near a large plate of resin that has undergone vigorous and prolonged friction, small *sparks* are emitted with a dry crackling noise. This is in reality a miniature thunder-storm: the spark is the lightning, and the crackling noise the thunder.

15. Bodies can be electrified by *friction*, by *contact*, or by *induction* (p. 50).

16. Power of Points (p. 51).—Electricity concentrates itself at the end of any pointed object, so that a pointed body which is a good conductor *discharges* its electricity at the point.

17. *Lightning-conductors* (p. 52).—This *power of points*, which induces lightning so frequently to fall upon spires and tall trees, etc., is applied to the construction of lightning-conductors.

18. A lightning-conductor is composed of a long pointed rod to which is attached a thick iron rod that descends into a well.

19. When a stormy cloud, we will suppose charged with *negative* electricity, comes near enough to the earth, it attracts all the *positive* electricity.

20. This being the case, one or the other of the two following phenomena must take place:

1. If the cloud be not too near, or if it be not too heavily charged with electricity, the electricity contained in the soil will glide gently towards the point of the lightning-conductor, and thence into the cloud, which will thereby BE NEUTRALIZED.
2. If, on the contrary, the cloud be heavily charged with electricity, the spark will spring between the conductor and the cloud, and the electricity will be guided along the iron rod and disappear in the well.

21. Fortunately, the greater number of flashes of lightning *pass from one cloud to another*, instead of passing between the earth and a cloud.

22. Electric Machines and Electric Batteries (p. 55).—Electricity can be artificially produced by two kinds of instruments, *electric machines* and *electric batteries* or *piles.*

23. The machines produce electricity by friction.

24. Electric batteries are made on the principle that *whenever a* CHEMICAL COMPOSITION OR DECOMPOSITION *takes place,* in other words, *in every* CHEMICAL REACTION, be it *strong* or *weak,* ELECTRICITY *is produced.*

25. Batteries give both negative electricity and positive electricity.

26. On bringing together the two wires which unite both electricities, an *electric current* is obtained.

27. From this current there can be obtained *physiological* effects (a trembling in the tongue, convulsions, sometimes even death), *physical* effects (deviation of the magnetic needle, sparks, electric light), and *chemical* effects (decomposition of water).

[Simple *Subjects for composition* are to be found at page 94].

VI.—MAGNETS.

53. Look at this horseshoe-shaped piece of steel (Fig. 83). To outward appearance it has nothing extraordinary about it. But see, if I present its two ends to a sewing-needle (Fig. 84), when within half an inch of it the needle *raises itself from the table, flies towards the instrument I present to it, and clings fast to it:* a sharp shake is necessary to make it quit its hold.

This piece of steel *which attracts both iron and steel* is what is called a MAGNET.

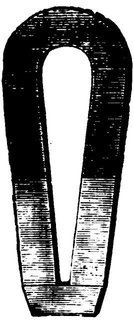

FIG. 83.—A magnet.

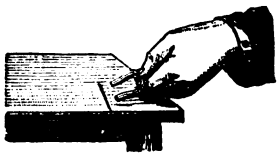

FIG. 84.—The needle flies to the magnet and clings to it.

54. Attraction of Iron by the Magnet.—Here mingled together and spread out upon a plate are some iron and copper filings, sawdust, cinders, coal-dust, and sand (Fig. 85).

What is the effect of the magnet on iron filings? What on copper and certain other bodies?

At some distance above the plate I pass the two ends of my magnet. *See how the iron filings are attracted by it and firmly adhere to it,* while the copper and all the rest remain quite still. THE MAGNET ATTRACTS IRON ONLY.

The action of a *magnetic bar* is almost exclusively *limited to its two ends.* You may observe that with the curved part of my magnet I can scarcely make the needle move

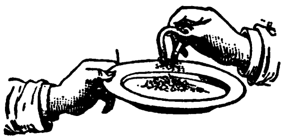

FIG. 85. — The magnet attracts iron only.

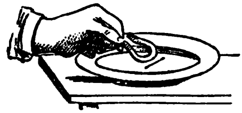

FIG. 86. — The curved part hardly acts at all.

(Fig. 86). And this is the reason why magnets are generally made in the shape of a horseshoe, so as to be able to act with both ends at a time.

55. Distant Action of the Magnet.—*Magnets*, as you see, *can act at a distance*, for the needle moved while the magnet was half an inch distant; and nothing can prevent this action. In proof of this I place the needle on a sheet of paper, on a bit of silk, or on a pane of glass (Fig. 87). You can pass the magnet under the object which thus separates it from the needle, and, *notwithstanding the obstacle, the needle faithfully follows the magnet in whatever direction it takes, the intervening body being incapable of preventing magnetic action.*

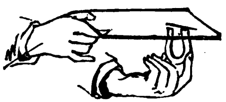

FIG. 87.—The needle follows the magnet even at the other side of the sheet of glass.

56. Magnetism by Contact.—Let us now put the needle upon the two ends of the magnet, and bring it near the iron filings (Fig. 88). The filings are immediately attracted towards the needle and adhere to it; thus, you see, *the needle has been magnetized by its contact with the magnet.* We may

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Do all the parts of a magnetic bar act in the same manner? Why are magnets generally made in the form of a horseshoe? Does the needle follow the magnet even when separated by glass?

now separate the needle from the magnet, it will nevertheless retain its power of attracting the iron filings (Fig. 89). *The needle has itself become a magnet.*

Even until lately this was the process by which all magnets used in physics were made. A piece of steel was rubbed upon a previously prepared magnet, which thus immediately magnetized the piece of steel. I say steel, not iron, for

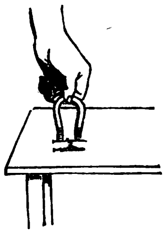

Fig. 88.—The needle is magnetized (magnetism by contact).

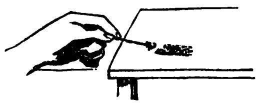

Fig. 89.—The two ends of the needle attract the filings.

although this latter is very *easily magnetized*, more easily even than steel, yet *it does not retain its magnetic power;* when iron is quite pure, it loses its magnetism as soon as its contact with the magnet ceases.

57. Natural Magnet.—What makes you look so perplexed when I say that magnets are made by rubbing a piece of steel with a previously magnetized magnet?—"I was wondering where the first magnet came from: it at least could not have been made by rubbing it against another, since no other existed."—Ah! well, that bit of curiosity will soon be satisfied; in fact, it was about this that I was just going to speak to you.

All magnets are not artificial: there exist also *natural* magnets. A certain iron-ore, called loadstone, has the power of attracting iron. This ore is abundantly found in Sweden, and also in Asia Minor, near an ancient Greek town, *Magnesia.* Hence the name of *magnetism* was given by the

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Can the needle in its turn become a magnet? How?

Greeks to the peculiar properties of this ore. This word is used with the same signification up to the present day. You understand now, do you not? *With natural magnets steel bars have been rubbed, from them artificial magnets have been obtained, and so on.* In our days people have other modes of arriving at the same result. I shall tell you of these in another lesson.

And now let us pass on to something else.

58. Magnetic Attraction and Repulsion.—Here is a steel knitting-needle. I magnetize it by rubbing it with a magnet: it attracts, as you see, the iron filings at both its ends. I suspend it by the middle to the stand (Fig. 90) we used in a preceding experiment. The knitting-needle moves about, *oscillates* as we ought to say, for a time, but finally comes to rest, and remains motionless in a certain direction.

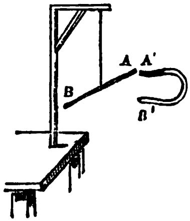

Fig. 90.—The extremities of the two magnets are attracted or repelled.

Then, to one end A of the suspended needle I present one of the ends A′ of my magnet: the needle is evidently attracted. And in that fact there is nothing to surprise us. But wait a little: wonderful things are to happen, only, as they are somewhat complicated in appearance, we take the precaution of marking A, A′, the ends of the magnet and of the needle which attract each other.

During this time the needle has become quiet again, and has returned to its first position. I present to the end A of the needle the end B′ of the magnet. Strange to say, the needle is repelled from the magnet. We will draw back our magnet, and wait till the needle gets settled again.

Let us see what will happen now if we put to the end B of the needle (the end we have not marked) the end B′ of the magnet: attraction is shown here also. Let us present the end A′: the needle is repelled.

So when we bring near each other two magnets, *their ends attract or repel each other* (Fig. 90).

How were the first magnets obtained?

Now, in order that you may understand all this clearly, I shall magnetize two knitting-needles A, A′ (Fig. 91) placed alongside of each other. For this purpose I set the marked end of my magnet on the middle M of the two needles, and

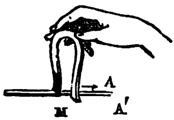

Fig. 91.—I several times rub the two needles from M to A, A′.

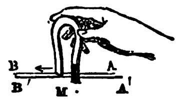

Fig. 92.—In the same way I rub the two needles from M to B, B′.

gently rub them with the magnet from the middle to one of the ends A, A′, repeating this operation several times. Then with the unmarked end of the magnet (Fig. 92) I rub from the middle to the end B, B′, the part of the needle that remained untouched the first time, and, as in the preceding case, repeat the rubbing several times.

The two needles are now magnetized. To avoid confusion, I shall put ink on the ends B, B′ of the needles (Fig. 93): then I shall suspend one of them by its middle, the one

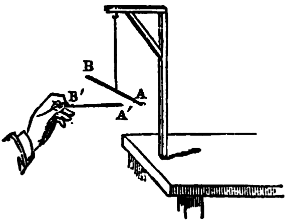

Fig. 93.—A′ repulses the extremity A, but B′ attracts it.

Fig. 94.—The duck is attracted or repulsed according as one or other end of the magnetized needle is presented to it.

marked A, B, for instance. You will subsequently see that if I present to the end A of the suspended needle the end A′ of the other needle, the end A will be repelled; if I present the end B, on the contrary, A will be attracted. The reverse will be the case if the end B be applied.

What is to be done in order to magnetize a needle by rubbing?

Thus there are at the two ends of one needle, or, to use the proper expression, at the two POLES, *two kinds of magnetism, as there are two kinds of electricity at the two ends of a body electrified by induction, or at the two poles of an electric machine.* It is perfectly evident that there is the same magnetism at B and B′ on the one hand, and at A and A′ on the other.

We can thus say that *poles of similar nature repel each other, while poles of opposite nature attract each other:* the rule is the same as that applicable to electricity.

You were aware of this fact, although unable to explain it, as you have all seen the small metal ducks that float on water and follow or flee from a magnetic needle according to the end presented to them; and this because in the duck's bill a piece of magnetized steel is hidden. Here is one of these toys (Fig. 94), and you see how very docile the good duck is.

59. Mariner's Compass.—And now let us return to our suspended knitting-needle. You see, of its own accord it has set itself in a certain direction; if I turn it aside, it swings awhile and then RETURNS to its first position. Now note in what direction it turns. *One end points to the north, the other of course to the south.*

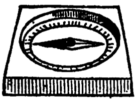

FIG. 95.—One end of the needle of the mariner's compass always points to the north.

THE MARINER'S COMPASS (Fig. 95), of which you all have heard, *is merely a magnetized needle*, but instead of being hung on a thread, in which case the instrument could not be easily carried about without damage, it is placed on a pivot, which allows it to turn freely in any direction. It is, moreover, shut up in a box with a glass lid, so that nothing can harm it.

It is quite unnecessary to mention the importance of the mariner's compass, and the immense service it renders to sailors on the trackless sea; for, as everybody knows, its needle, constantly pointing to the NORTH, allows the cardinal points to be found under any circumstance whatever.

It is, however, necessary that there be no other magnet

In what do the two ends of a magnetized needle differ? What are the laws of magnetic attraction and repulsion? What direction does a magnetic needle take when suspended? What is the mariner's compass?

and no mass of iron in the immediate neighborhood of the compass, otherwise the needle would deviate and give false indications. On board iron-clad vessels the regulation of the magnetic needle is therefore no easy matter.

The compass has been used in Europe for four or five centuries, but it was known to the Chinese long before that.

60. Magnetization by the Electric Pile.—I have already told you that magnets are no longer generally made by rubbing steel with another magnet. The other process I promised to explain is the following, and in order to make the explanation as attractive as possible I shall make a magnet before you. For this purpose I take a nail A, B (Fig. 96), of wrought iron; around it I wrap some straw, which is an insulating body; then, taking one of the wires C of the electric pile we made a little while ago, I wind it a great many times round the straw. You can convince yourselves that at present the two ends of the nail, which are not covered by straw and wire, have no attractive effect on the iron filings. Things being thus prepared, *I bring together at* E *the two wires* C, D, *of the pile, otherwise called the two poles; the electric current passes and circulates* AROUND *the nail; immediately the latter is magnetized and exercises attraction upon the iron filings.* When I interrupt the current by separating the wires C, D, the iron filings fall off; when I again allow the current to pass, the filings cling once more to the nail, and so on.

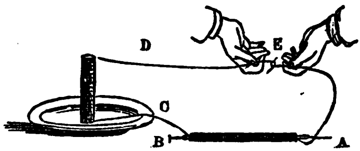

FIG. 96.—As soon as the electric current is passed through the wire, the nail B, A, is magnetized (electro-magnet).

Thus we have made what is called an ELECTRO-MAGNET, a word easily understood. Ours is of course a very weak one, for it can scarcely lift tiny iron filings. But with strong currents electro-magnets have been made capable of lifting and holding suspended several tons' weight.

What should be done in order to magnetize a nail by the pile? Your arrangements being completed, what is now necessary in order to magnetize the nail? What name is given to iron thus magnetized?

Electro-magnets constitute the fundamental part of the *electric telegraph*, one of the many marvellous applications of electricity.

SUMMARY.—MAGNETS.

1. **Magnets and Magnetism** (p. 61).—A magnet is a piece of steel which has the power of attracting iron.
2. This power has been called MAGNETISM.
3. If a steel needle be rubbed with a magnet it will manifest magnetic power.
4. There are *two sorts of magnetism,* just as there are *two sorts of electricity.*
5. If one of the extremities or *poles* of a magnetized needle take one sort of magnetism, the other extremity will take the magnetism of the opposite sort.
6. Poles of similar nature REPEL each other; those of different nature ATTRACT each other. (The rule is the same as that applicable to electricity.)
7. **The Mariner's Compass** is merely a magnetized needle placed upon a pivot. When at rest, one end of the needle is constantly directed towards the NORTH.
8. At the present day iron or steel is magnetized by the action of electric currents. This is the principle of the *electric telegraph.*

[Simple *Subjects of composition* are to be found at page 94.]

VII.—WEIGHT, AND GRAVITATION.

Weight and Density.

61. Force of Gravity.—I hold in my hand a small stone and a sheet of paper. I let both go at the same time, and the stone falls straight to the ground, while the paper floats and oscillates an instant, but finally reaches the floor. What I have done with these two bodies I might have done with many others: *let go in the air, they would have fallen to the ground.*

I take the paper and the stone in my hand once more; but this time before I let go the paper I shall crush it up into a ball, as small and as tight as possible. There, look: this time the paper ball falls as rapidly as the stone, and both reach the floor at the same moment.

This is one demonstration of the fact that all bodies fall with equal rapidity: when differences exist they are caused

solely by the resistance of the air, which is greater or less according to the extent of surface presented to it, the greater surface of course offering the greater resistance.

Stand forward and hold out your open hand (Fig. 97). Here is a small ball of lead. I shall let it fall into your hand

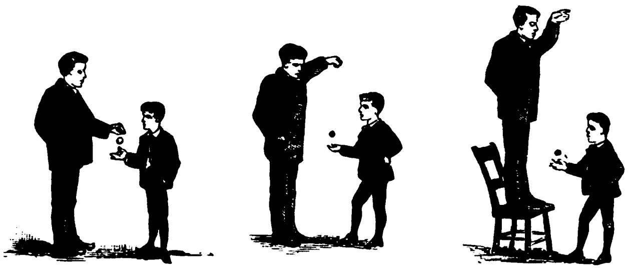

FIG. 97.—"That does not hurt me." "This time I felt it more smartly." "This time it makes my fingers tingle."

from the height of about three inches. That does not hurt you, does it?—"No."—Well, this time I shall hold it a yard high before letting it fall.—"Ah! this time I felt it more smartly."—Well, let us try once more. This time I shall get upon the chair and let it drop from twice the former height.—"Ah! this time it makes my fingers tingle."—Then that is enough. Now, what should we conclude from this experiment? We must evidently conclude that *the longer the fall lasts, the greater is the force that the body acquires, or, in other words, the greater the distance through which a falling body has to pass, the greater is the rapidity attained.*

And this rapidity, when the body falls from a great height, is so considerable that one cannot see it pass. For instance, during the first second a falling body travels 16 feet 1 inch; the same body, in 2 seconds, passes through 64 feet 4 inches; during the 5th second, about 145 feet; and about 306 feet during the 10th second of its fall; and so on, always increasing

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As all bodies fall with the same rapidity, how is it that a sheet of paper falls less quickly than a stone? What conclusion may we form from the falling of bodies?

its velocity more and more. Thus, were you to jump out of the school-room window, which is 3½ feet above the level of the court-yard, you would do yourself no harm; but were you to fall from the church steeple, which is 50 feet high, your bones would be broken by striking the ground.

62. The Vertical.—A body that falls to the ground follows no capricious or uncertain course. If it has not been thrown, *it will always fall in a straight line* A, B (Fig. 98) *which is perpendicular to the surface of water.* This line is

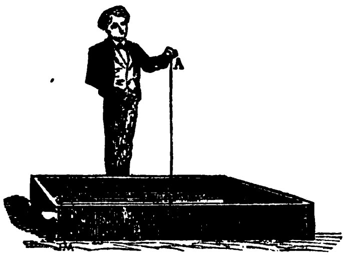


FIG. 98.—The vertical line A, B is perpendicular to the surface of water.

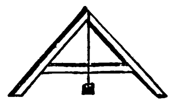


FIG. 99.—Plumb-line used by masons.

called VERTICAL. In order easily to find the vertical line, a somewhat heavy body is suspended to the end of a string; the weight of the body causes the string to hang vertically. This string with its heavy body is what is called a *plumb-line* (Fig. 99).

63. Weight of Bodies.—This time, hold out both your hands. Do not be afraid: I shall not hurt you. I merely wish to put in one, A (Fig. 100), a piece of cork, and in the other, B, a piece of lead of equal dimensions. What difference do you find between these two bodies?—"Oh, the lead is much *heavier* than the cork."—Very well; but tell me what you mean when you say it is "*heavier*."—"Well, I think it is *that I have greater difficulty in keeping it from falling.*"

What direction does a falling body take? What is its line of descent called? How may a vertical line be easily found? What name is given to an instrument constructed to show this? What is meant when we say that one body is heavier than another?

Exactly so. *All bodies fall with equal rapidity, but not with equal force.* You could hardly bear the fall of the lead ball I dropped from the height of two yards a little while ago, while you might catch this cork in your hand without harm were

FIG. 100.—The piece of lead is much heavier than the cork.

it thrown from the top of the house. *A body that falls with greater force than another is said to be* HEAVIER, *or weightier, than another.*

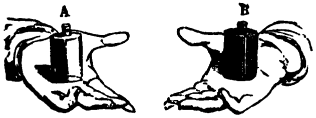
64. Density of Bodies.—All this is not so simple as it looks. Once more stretch out both hands. This time I put in them a little piece of lead and a little piece of cork. The lead is still the heavier, is it not?—"Yes."—Very well; but now I heap on your hand a great many pieces of cork until your hand is full. Which is the heavier now, the lead or the cork? —"Ah! now it is the cork; but that is not surprising, for it is ten times bigger than the lead."—Surprising or not, it is nevertheless true that the cork is now heavier than the lead. What can you say to that?

"Ah! *in order to compare the weight of the lead with the weight of the cork, it is necessary that both be of* THE SAME SIZE."—Quite right. We will, then, conclude that a body is "heavier" than another, or, in other words, that it has a greater WEIGHT than another, when it falls with greater force than the other, *whatever be its volume:* thus, we say, a large cork is "heavier" than a little ball of lead; but when of two bodies of EQUAL DIMENSIONS one is heavier than the other, we may conclude that the heavier is "DENSER;" the lead, then, is "denser" than the cork.

But it is not only solid bodies that have greater or less

What conditions ought two bodies to present if we wish to compare them? When is it said that one body is heavier or weightier than another? When is it said that one body is denser than another?

weight, greater or less DENSITY. Here is a small bottle, A, full of water (Fig. 101), and another, B, of equal size, full of mercury. Weigh them in your hands as you did with the lead and the cork. What a difference there is between them! And no wonder; for a *certain volume of mercury is* 13½ *times as heavy as an equal volume of water;* or, to use another expression, *the density of mercury is* 13½ *times greater than that of water.* For convenience' sake, people have agreed upon taking water as the standard in this matter: *the density of water, then, being* 1, *that of mercury must be* 13½, or, more exactly, 13.6.



A, water. B, mercury.

FIG. 101.—The density of water, A (weight of the same volume), being 1, that of mercury, B, is 13.6.

In like manner it is said that the density of lead is 11.4; that of gold, 19.3; that of iron, 7.8; that of ordinary stone, 2.7; that of glass, 2.5; that of oak wood, 0.6; that of wine, 0.9; that of pure alcohol, 0.8.

Lastly, *gases also have weight* and different degrees of density. Air is only $\frac{1}{773}$ as heavy as water; yet it weighs something, for a bottle full of air is heavier than one from which, by means of an air-pump, the air has been totally removed.

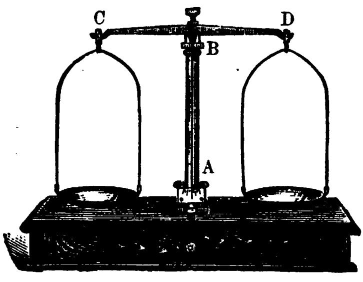


FIG. 102.—Ordinary scales. CD, beam.

65. Balances.—You were easily able to tell me a little while ago that the piece of lead was heavier than a piece of cork of the same size, and this simply by weighing them in your hands; but that was because the difference was very considerable. You would not be able to detect slight

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Explain what is understood by the word *density*, taking for example water and mercury. Name the density of some other bodies. Has air any weight? What is the weight of air as compared with that of water?

differences. In such cases you must have recourse to instruments called BALANCES, or SCALES. There are several kinds of balances. The simplest and most in use (Fig. 102) are composed of a vertical stationary rod AB, and a horizontal movable rod CD, supported exactly at its middle on the top of the vertical rod. At each end of this horizontal rod, called the *beam* of the balance, two pans are hung. *When these pans and their suspending chains are exactly of equal weight, the beam remains perfectly horizontal, and the index-needle points to the middle of the scale.* So it remains if an equal weight is placed in each pan. But if there be additional weight in one pan, the pan containing the heavier object will descend.

With such an instrument one not only learns whether two bodies have equal weight, but the difference between them can also be ascertained. For this purpose the body whose weight you wish to know is compared with others of which the weights are previously known, and which are used as standards or units. The principal unit or standard in the metric system is the *gramme*, the weight of a cubic centimetre of distilled water.

66. How to Measure the Weight of Solid Bodies.—I put in one of the scales the body which I desire to weigh; let it be this piece of lead, for instance. In the other I place weights until the beam becomes exactly horizontal. I have then only to add up these weights to ascertain what the piece of lead weighs.

The balance I have described is the common rather old-fashioned balance, with the pans hung under the beam. Many other sorts exist, but we have not time now to consider the details of their mechanism.

67. How to Measure the Density of Solids.—Now, if with the help of my scales and my piece of lead I wish to calculate this time not the *weight* but the *density* of lead, I can very easily do so.

I already know the weight of this piece of lead (I shall call it W). If I knew the weight of a volume of water equal to that of the lead and called that weight w, I should only have to divide W by w, and the ratio $\frac{W}{w}$ would give the density of the lead.

In the first place, however, the volume must be ascertained; and that seems rather difficult on account of the irregular shape of the piece of lead. This difficulty will be easily overcome by taking a vessel the capacity of which has been measured, and on which different measures are indicated by figures: this vessel is what is called *a graduated gauge.* I pour in water until it rises to the number 100. Then I drop into the vessel the lead, whose weight I have found to be 85.5 grammes; the water rises to 160. What is the volume of the lead?—"Evidently it takes up 60 divisions."

FIG. 103. — The level of the water, which was at 100, rises to 160: the difference indicates the volume of the lead A.

Now, I know the weight of the water that fills up those 60 divisions of the gauge: it is exactly 7.5 grammes; I have thus the weight w; I measured W directly. The density, then, is $\frac{W}{w}$; that is to say, in short, 11.4. So the lead weighs proportionately 11.4 times heavier than water.

You see that the density of lead is less than that of mercury. Strange enough it is to see a piece of lead float on the surface of mercury as a cork would float upon water.

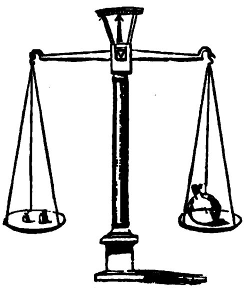

FIG. 104.—How to ascertain the weight of a liquid or of a gas.

68. How to Measure the Density and the Weight of Fluids.—When we wish to weigh a solid, nothing is more simple: we put it directly in one of the scales, while in the other we add weights until we balance both.

In order to know the weight of a liquid, we put it into a vessel and weigh both together; afterwards we ascertain what is the

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What is the density of lead? Of mercury? How would you ascertain the weight of a liquid?

weight of the empty glass, and deduct its weight from that which we found for the whole.

Thus it is that we ascertain that mercury weighs 13.6 times as much as an equal volume of water: consequently its density is 13.6. In like manner we find that the density of ordinary ether is 0.7, the density of water being always taken as a standard.

The weight and density of gases are ascertained in like manner.

In the case of air, for instance, a bottle full of air is weighed in the first place; then, with an air-pump, the air is removed. The bottle, of course, then weighs less. The difference is evidently the weight of the air removed. The volume of the bottle being known, the density of the air may be calculated. It is 773 times lighter than water.

69. Relation between Temperature and Density.—When it is said that the density of gold is 19.3, that of mercury 13.6, and that of air $\frac{1}{773}$ that of water, it is necessary to specify that these measures have been taken at the temperature of 0° centigrade.

Do you see the reason for this? Do you know whether a cubic inch of gold at 0° will weigh more or less than a cubic inch at 100° centigrade?—"It will always have the same weight, for it will always be a cubic inch."—You are mistaken there. Listen to this.

Here is the cubic inch of gold. At the freezing-point it weighs a certain amount. If I put it in boiling water it will expand, as I have already told you. So it is no longer a cubic inch, but a cubic inch and something over. If I pare off this something over, it is evident that the weight will be diminished. Therefore at 100° the cubic inch of gold will weigh less than a cubic inch at zero.

As LIQUIDS expand much more than *solids*, the differences in their density at different degrees of temperature are still more important.

But these differences are nothing compared to those given by GASES, on account of their excessive elasticity. A given

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How would you find the weight of a gas?

volume of air at 0° *increases about a third part of its bulk* when heated to 100° centigrade. So the weight of a volume of air at 100° is one-third less than that of an equal volume at 0°.

You can see from all this that it is absolutely necessary when speaking of the density of gases and liquids to mention at what temperature they were measured. And, to simplify things as much as possible, the temperature of melting ice is always taken as a standard. The only exception made is in the case of water, whose density is taken at 4° above zero of the centigrade scale. Thus, when it is said that a cubic centimetre of water weighs a certain amount, you must know that it is at 4 degrees. For, strange to say, it is at the temperature of 4° centigrade, or about 39° Fahrenheit, that water attains its greatest density.

Now I hope you all know with sufficient accuracy what is meant by the *weight* and the *density* of a body, and that you are also capable of finding both.

Pressure of Liquids.

70. Outflow of Liquids.—Let us go now into the garden and see what we can learn from the humble water-cask. I have turned the tap at the bottom, and the water gushes forth, shooting out to a good distance. If you put your hand in the jet, you will find that the water comes out with considerable force.

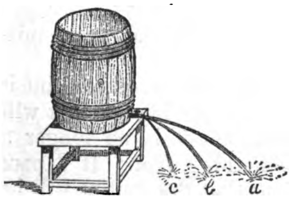

Fig. 105.—As the cask becomes empty the jet grows less and less strong, and goes back gradually from *a* to *c*.

As the cask becomes empty the *jet diminishes in strength:* from *a* (Fig. 105) it goes back gradually to *b*, then to *c*, and *finally the water would fall almost straight down.* But you know all that: so I turn off the tap, as we shall require more water in a short time.

Were I to ask you what makes the water shoot out thus,

I turn on a tap placed at the bottom of a cask full of water: what happens to the jet when the cask is nearly empty?

what reason could you give?—"It is the weight of the water in the cask, since the more water there is the stronger the jet is. *It is the water that pushes.*"

71. The Pressure depends upon the Height.—Quite right: it is the water that pushes. But it is not, as you might suppose, the whole bulk of the water: *the quantity that there is in the cask has nothing to do with the matter: it is the* HEIGHT *of the water above the jet that is important.*

Now let us return to the school-room: I shall there prove to you, with a very simple instrument, what I have just asserted.

This instrument, which I made with my own hands to avoid expense, is composed of a tin tube AB (Fig. 106), well corked at the lower end. I have pierced in it a little hole at C, corked, also, for the time being. At A I have

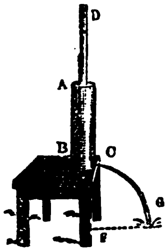

FIG. 106.

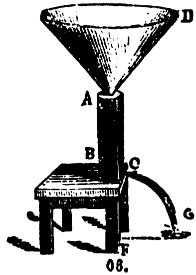

FIG. 107.

Whether there be a simple tube AD, or a large funnel, the water flows to G, 8 inches from F; for it is not the quantity of water that influences the force of the jet: *it is its height that is important.*

adjusted a second tube D, much narrower than the first, and the whole is filled with water to a certain height. The instrument contains, as I have previously measured, 60 cubic inches of water, 10 of which are in the tube D. I now withdraw the little cork, and the water springs out to a good distance, and reaches G, but it rapidly loses strength and falls close to the tube. Let us measure the distance G. It is 8 inches.

I cork the hole again, and instead of the little tube on the top I put a large funnel D (Fig. 107), and pour in

water to the *same height* as before. For this I have required 300 cubic inches of water, 100 of which are in the funnel: so that *it contains* 10 *times more* than the little tube. When the cork is taken out, will the water spring to a greater distance than it did before?—"Yes: as the amount of water in the funnel is ten times greater than the amount in the tube, it will push ten times harder."—Ah! you are wrong there. But pull out the cork and learn for yourself. See, *the water shoots no farther than* 8 inches. The jet lasts much longer, because there is a greater quantity of water; *but it has no greater force than in the first case. You see, then, I was right in saying that* HEIGHT *alone is important.*

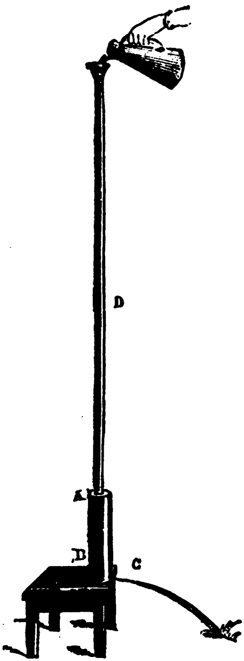

FIG. 108. — The pressure has made the little cork fly out, although there is less water in the tube than in the funnel, because the *height* CD is much greater.

I shall give you another proof. Here is a tube similar to the first, except that it is five times as long (Fig. 108); it contains only half the quantity of liquid that was in the funnel. This I fix on my tin tube, and begin to pour water into it. Bang! out flies the cork C before the upper tube D is half filled, and the jet shoots a distance of at least 15 inches. What can be the reason of this? It is, that the pressure of the water was so strong that the cork was unable to support it; and yet there was less water than was in the funnel a short time ago.

72. Measure of the Pressure.—*This leads to the conclusion*

I procure a simple tin tube and a funnel: what will become of the jet of water which I allow to flow from the side at the bottom of the tin tube?

that the pressure of water on the bottom of a vessel depends entirely on the HEIGHT *of the water.* So, if you pour water into a vessel the bottom of which has a surface of one square inch, until it reaches the height of one inch, the pressure it exerts is equal to the weight of a cubic inch of water. If the water poured in reaches the height of ten inches, the pressure exerted will be equal to the weight of 10 cubic inches of water, and that *whether the vessel be* TUBE-*shaped or like* a FUNNEL.

Very evidently if the bottom of the vessel presented a surface measuring 2 square inches the pressure of water an inch deep would be equal to the weight of 2 cubic inches of water; a depth of 10 inches would likewise give a pressure equal to the weight of 20 cubic inches. For, naturally, each square inch of the surface of the bottom supports on its own account an equal weight.

A very simple experiment will show clearly the pressure of liquids, and give us at the same time its measure.

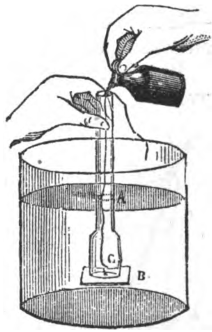

FIG. 109.—The card-board B, sustained by the pressure the water exerts upon it from below, does not fall until the water poured into the lamp-glass is on the same level as that in the vessel.

I take the glass chimney of a common lamp (Fig. 109), and put below it a bit of card-board B that fits closely against it. I then plunge the whole into a vessel full of water. The pasteboard, which I kept close to the lamp-chimney at first by a thread, remains in its place without any other help than the upward pressure exerted upon it by the water in the vessel. I then pour water into the lamp-glass. As soon as the water reaches the same level as the water in the vessel, the card-board is displaced and falls to the bottom. This indicates that the pressure exerted from *below* on the card-board was equal to a column of water having for base the opening C of the lamp-glass, and for *height* that marked C, A.

Why has the jet of water coming from the funnel no more force than that coming from the tube?

73. Influence of the Density of Liquids.—Of course the greater the density of a liquid, the greater will be the pressure of a column of that liquid. Therefore it is evident that since the density of mercury is 13½ times as great as that of water, the pressure of a column of mercury 1 foot high is equal to the pressure exerted by a column of water 13½ feet high.

74. Equilibrium of Pressure.—Tuck up your sleeve, and place your hand flat (Fig. 110) on the bottom of this pail of water. Do you feel anything?—"The water is very cold."—That may be, but that is not what I want to speak about. Do you feel the water weigh on your hand.—"No, not at all."—And yet do you not think it ought to weigh?—"Yes, of course, for my hand is at the bottom of the pail."—Here, then, is something new: the weight of the water is on your hand, and yet you do not feel it.

But, in the first place, compute how much the water should weigh on your hand. The height of the water in the pail is 10 inches, and I suppose the surface of your hand would measure about 6 square inches. But in order to get on faster I shall calculate in your stead. So there is weighing down upon your hand a column of water measuring $10 \times 6 = 60$ cubic inches, the weight of which presses down upon your hand, and yet you are not conscious of it.

FIG. 110.—You do not feel the weight, because the water weighs equally on *all* parts of your hand.

Suppose now that a fish whose body presents a surface of 6 square inches swims 100 inches deep. It has to support a pressure equivalent to the weight of 600 cubic inches. Fishes have been found in the sea at such depths that, supposing the surface of their body to be 6 square inches, they had to support the weight of 20,000 pounds (Fig. 111). Twenty thousand pounds' weight upon the body of a small fish, and yet it is not crushed: it even has no difficulty in swimming.

This is very strange, is it not? And yet it is quite natural.

You place your hand flat on the bottom of a pail of water: how would you calculate the pressure exerted on your hand?

How could the fish be crushed? *The body is composed of solids and liquids, and we have seen that solids and liquids are almost incompressible, hence almost incapable of being crushed.*

"But——" —Well, what? say on.—"You say that solid parts and liquid parts cannot be crushed; yet only yesterday I saw our neighbor the blacksmith crush his finger under his hammer. The bruised part was quite in a pulp. It was horrible, and the finger had to be cut off."

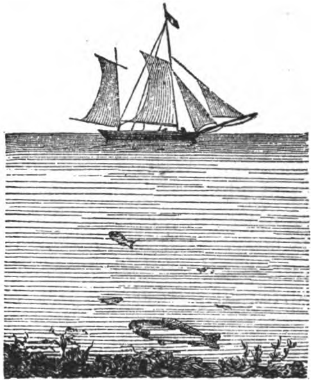

Fig. 111.—The fish is not crushed, because the pressure is exercised equally on *all* parts of its incompressible body.

That is sad, indeed, poor man. But, to continue our study, I must say that you are quite right to ask the explanation of things you observe, and I am happy to give the information you desire. These things are not easy for you to understand, and yet it is necessary for you to understand them. Put your hand on the table, just as the blacksmith had his on the anvil. There, now; I intend to strike upon your finger with a hammer. Don't be afraid: I shall strike very gently. Do you see how the hammer acts? It strikes only on the upper part of the finger, while the table is in contact with the under part. But on the *two sides* of the finger *nothing touches* or *sustains* it. The flesh thus pressed between the table and the hammer, were I to strike forcibly, would escape *sideways*, as a cherry-stone would shoot out between your fingers, and would thus tear open the skin: the finger would then be crushed.

But if there were all *around the finger* a resistance equal to the force of the blow of the hammer, there would be no crushing, neither sideways nor endways, nor above nor below the finger. And as this resistance would be absent only on the part where the finger is joined to the body, in that direc-

tion only would the crushing or bruise be able to exert itself. If, in its turn, the whole body were *completely surrounded* by resistance equal to the force of the stroke of the hammer, crushing could take place in no direction whatever, and, the body being incompressible, there would be no bruise.

I speak, of course, of a body in which there is no gas, no air like that we have in our chest, which is very compressible indeed. We should soon be crushed to death were we to be plunged 3000 feet under water, leaving drowning out of the question. What I have just said will enable you to understand why a fish is not crushed to death in the water notwithstanding the enormous pressure that sometimes bears upon its body. *For the pressure is exerted exactly in the same proportion all over its body, so that there is no reason why any particular part should give way and be crushed.*

Pressure of the Air.

75. Atmospheric Pressure.—I have explained the case of the fish, because we are in a similar position, and are likewise pressed on all sides, bearing on our body an enormous weight that no more crushes us than water crushes the fish. But this time it is not water that we have to deal with: it is *air*.

FIG. 112.—The air in the bottle, dilated by the heat of the burning paper, made a vacuum in cooling. It was then that the atmospheric pressure pushed the egg into the bottle.

In fact, *air weighs on us just as water weighs on the fish.* And this weight, of which you take no heed, and under which you run and leap so lightly, may be estimated for you children at about 20,000 pounds.

Here is a very simple and amusing experiment, that will give you an idea of the pressure of air. I take a wide-necked bottle, and a hard-boiled egg (Fig. 112) the shell of which has been carefully taken off. You see the egg fits nicely into the neck of the bottle. But I shall not leave it there. I

Why is a fish not crushed in the water? What is the pressure that air exerts on us? How great would you suppose this pressure to be?

see you think this is a very funny and not very scientific-looking experiment. But listen and observe, and you will see that the experiment has more importance than you might at first imagine.

I now put into the bottle a bit of burning paper. When the paper is almost consumed, I replace the egg on the neck of the bottle. Wait a moment: you see the egg is sucked gradually down, and then all at once enters the bottle with a loud report. What has pushed it in? *Simply the weight of the air.*

And how? You now know enough of physics to follow and understand my explanation.

The burning paper heated the air contained in the bottle. The air expanded by heat found no longer sufficient room in the bottle, therefore a considerable quantity, perhaps one-half, was expelled and mingled with the surrounding atmosphere. At that moment I placed the egg on the neck of the bottle, completely stopping up the opening. When once the bottle was a little cooled, the air it contained *tended to return to its original volume*, which the heat had doubled. In that condition *it no longer opposed sufficient resistance to the outward pressure of the air*, so that the egg, soft and easily lengthened out, being unsustained from below and pressed upon from above, gave way under the effort of the external air, and was thereby pushed into the bottle.

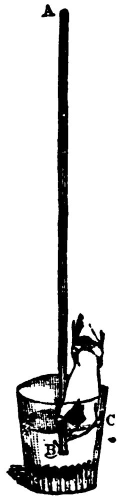

FIG. 113. — The tube closed at A, open at B, remains full of water, and does not empty itself in the glass. It would be the same for a tube that was 11 yards high.

76. The Measurement of the Weight of Air.—Another experiment may be made. Here is a glass tube about 3 feet long (Fig. 113): it is solidly closed at one end by a cork well surrounded by sealing-wax. *I fill this tube with water;* then with my finger I stop up the open

Why does an egg sink into a bottle in which a vacuum has been made?

end, and invert it into a glass filled with water. I withdraw my finger, *the tube nevertheless remains full. The water does not fall into the glass, but remains supported,* 3 *feet high in the tube.*

What can thus sustain it? *The pressure that the air exerts upon the surface* C *of the water in the glass,* and consequently upon B at the under surface of the column of water, but it cannot, on account of the cork, exert its force on the upper surface at A. The proof of this is, that if the cork be taken away the whole contents of the tube will run out and pass into the glass, as it is easy to show you.

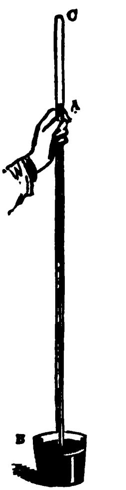

Fig. 114.—A column of mercury AB, 2 feet 6 inches high, is supported by the atmospheric pressure.

If the tube were 2, 4, 6, 8, 10 yards long, the result would be the same. But were it much longer, 12 yards, for instance, *we should find that the water poured into it would not stand higher than about* **33.8 FEET** *above the surface of that contained in the vessel into which the tube is plunged.*

This very clearly shows that the *pressure of the air, or, to use the expression employed in physics, the* BAROMETRIC PRESSURE, *is capable of holding in equilibrium a column of water* 33.8 *feet high.*

But it would be no easy matter to construct or to handle a glass tube of this length, and I do not think that in schools, at all events, experiments will ever be made with such instruments. In fact, there is no reason why they should be, for we have a better way of going to work.

77. Barometer.—We have, as you will remember, at our disposal another liquid, *mercury,* whose density is about 13 times greater than that of water. It is, then, easy to understand that a column of mercury 1 foot high, for instance, will be of the same weight as a

I place in a glass of water a tube full of water, and the water does not run out: what prevents it? If my tube full of water had been twelve yards high, what would have happened? What does that imply?

column of water of the same diameter and 13.6 feet high. Therefore, to have the equivalent weight of a column of water 33.8 feet high, a column of mercury of $\frac{33.8}{13.6} = 2$ feet 6 inches would be required.

A tube of this length is manageable, and we will forthwith set to work and see if our calculation gives us the result we obtain. I shall take the tube we were using a little while ago, and in order to be sure of the stopping of the upper end I shall close it (Fig. 114) by melting the glass in a strong flame so as to seal it up.

There, it is all right, and the tube cooled. I now proceed to fill up the tube with *mercury*, and, as I did a little while ago, stop up the opening with my finger and immerse it in a glass B containing also some mercury: immediately some of the mercury runs out of the tube; the column sinks and stands still at a certain point. Hold the tube erect while I measure at what height the mercury in the tube is above the level of the mercury in the glass. *I find it to be* THIRTY INCHES, just what we found by calculation.

This tube full of mercury is what is called a BAROMETER, from two Greek words, *baros*, weight, and *metron*, measure.

78. Relation between the Height of the Barometer and the Altitude of Places.—If, instead of making the foregoing experiment here, in this low-lying country, we had gone to fill our tube with mercury on the top of some mountain, *the column of mercury would not have stood so high.* At the top of Mont Blanc (5243 yards) it would have fallen to 16 inches and a half. In the balloon-ascent of the 15th of April, 1875, in which two Frenchmen, Sivel and Crocé-Spinelli, lost their lives from asphyxia, at the height of 9370 yards the mercury fell to 10 inches.

And this is quite easy to understand, since *the higher one rises the less air remains overhead:* consequently, *the less the*

I replace the water by mercury: how high a column of mercury can the atmospheric pressure sustain? Why? What name is given to an instrument thus constructed? What would have happened if instead of filling the tube in a low-lying country it had been filled on the summit of Mont Blanc? Explain this diminution in the height of the barometer.

air presses down, the less power it has to sustain a column of mercury.

Thus you see that the height of the barometer is not the same in all parts of the world. Besides, it varies in a given place according to different circumstances, especially in unsettled weather.

79. Measure of Barometric Pressure.—If we, then, consider that the mean pressure, at the level of the sea, is able to support a height of 30 inches of mercury, or 33.8 feet of water, we must conclude that each square inch of surface bears a barometric pressure equal to the weight of about 15 pounds; for this is the weight of a column of mercury one inch square and thirty inches high. This is what is expressed by the words an ATMOSPHERE of pressure.

Let us apply the knowledge of this fact to the experiment we made with the bottle. The heat had expelled about half of the air; therefore, after cooling, the egg was PRESSED upon by all the weight of the air, by a whole atmosphere, and was *upheld* by only *half* an atmosphere; that is to say, the downward pressure was greater than the upward by half an atmosphere, or 7½ pounds to every square inch of the surface of the opening of the bottle,—evidently much more than was necessary to push the egg into the bottle.

It has been calculated that when the air is heaviest a man of average height sustains a weight of about fifteen tons, which he does not even feel, for reasons similar to those given in the case of the fish in connection with the pressure of the water. And as the air is, by the mouth, in communication with the chest, we cannot be crushed. When one ascends to the top of Mont Blanc, the pressure is about 8 pounds per square inch. But that does not matter, since everything is in equilibrium, and the difference is unfelt. The disagreeable sensations and weakness that overcome travellers on high mountains arise from another cause.

And now I hope you all understand *weight*, *density*, and *pressure*. You should also know how to measure them, what a *balance* or scales are, and also all about the *barometer*. These are very important matters, and if you have properly understood them many difficult things will be but pastime for you.

80. Balloons.—As I told you at the beginning of our lessons on weight, all bodies fall towards the ground, unless something keeps them up. I should not have been surprised had some of you interrupted me at that moment; nobody did so, however. I must not allow those statements to pass without saying something about the little air-balloons which are made for children (Fig. 115), and which have to be held by a string to keep them from flying away; you might also have mentioned the real large balloons (Fig. 116) which rise in the air and are able to carry in their cars several

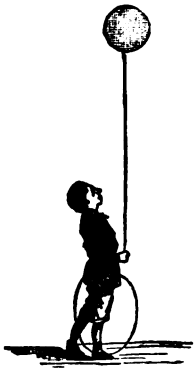

FIG. 115.—These little balloons are filled with a gas lighter than air (hydrogen).

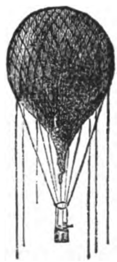

FIG. 116.—Large balloons contain the same gas that is used for lighting the streets, houses, etc.

FIG. 117.—The cork let go in the water rises to the surface.

men. These are exceptions, are they not? Well, no, they are not exceptions.

Do you remember anything else that rises when let go, instead of sinking?—"No, nothing at all."—Come here to me; take this cork, put your hand down with it to the very bottom (Fig. 117) of this pail of water, and once there let it go.—"Ah! it is not worth while: I know very well the cork will come to the surface."—Oh! you should have thought of that immediately. Yes, it will come to the surface; but for what reason?

Which is the less *dense*, the cork or the water?—"The cork, since it rises."—Yes, the cork is *less dense* than water, and it weighs less than *an equal volume of water;* that is to say, it would fall with less force. In consequence, if you let it go when under water, the water immediately above it will *fall* with greater *force* than the cork can, and so, going below the cork, will push it upward. And this will go on until finally the cork comes to the surface.

Let us make the experiment with a slight alteration. Before putting the cork under water I stick into it a pretty large nail. You see the cork comes up, nail and all. But if I add another nail, and let the cork go midway between the bottom and the surface, it not only does not rise, but sinks slowly down.

Well, it is just the same thing with the balloon. *The balloon is a kind of bag containing gas, lighter, less dense, than air.* Sometimes it is heated air, sometimes the gas we burn. The balloon rises through the air just as the cork rises through the water; and, just as the latter was able to carry along with it a nail, the balloon can carry with it a car containing several men.

You see you can understand this very easily; it seems quite simple to you. Why? Because you know what density is.

81. Application of the Principle of Atmospheric Pressure.—I can show you another application of the principle we have learned to understand. On the surface of the water in the basin T (Fig. 118) I put a piece of cork, and on the cork a piece of burning paper. Then over the cork and the paper I invert an empty glass, which I push gently down into the water; big bubbles of air immediately escape from under the glass, and the paper ceases to burn. *Soon you see the water rise in the glass so as almost to fill it up to* AB. Can you explain this?—"Yes, I think so. The paper, burning under the glass, heated the enclosed air and caused it to expand, so that all of it could no longer remain in the glass; some escaped in bubbles. Then the air cooled

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Why can balloons rise in the air?

and contracted, allowing the water to rise in the glass and fill up the space left vacant."—Very well; but what forced up the water?—"The *atmospheric pressure* upon the surface of the water in the basin."

Now look here: I incline the glass in the water so as to

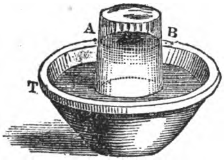

Fig. 118.—The burning paper has produced a vacuum in the glass. This space becomes filled with water, which is pushed by atmospheric pressure, and rises as high as AB.

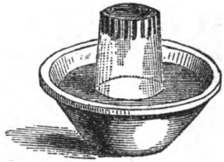

Fig. 119.—The water which fills the glass is maintained by atmospheric pressure, which acts on the water in the basin.

fill it. I then lift it (Fig. 119), and yet the water does not fall: how is this?—"You have made a sort of barometer, and the water remains in the glass for the same reason that the mercury remains in the tube of the barometer."—Very well answered.

82. Cupping-Glass.—Again I resort to my glass, which has already helped me to show you so many wonderful things. This time I light a piece of paper in it, then I apply the mouth of the glass to my arm (Fig. 120), making sure that the edge fits nicely on the skin all around. The paper immediately ceases to burn, and in a few minutes my skin swells out and is sucked into the glass. It holds very fast, and I should have great difficulty if I wished to pull it off at once; but if I loosen the least bit of the edge it comes off quite easily, and even falls off as soon as the air gets in. You see clearly that this is just what happened with the water in the preceding experiment. *Part of*

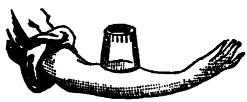

Fig. 120.—The burning paper has produced a vacuum in the glass. My skin, under the atmospheric pressure, is sucked into the glass, so as in part to fill up the vacuum.

What causes water to rise in a glass in which a vacuum has been made? Why does the skin in part fill up a glass in which a vacuum has been made?

the heated air was expelled from the glass by expansion, and when what remained had cooled, its contraction formed in the glass a partial "vacuum," which the skin, under the atmospheric pressure, tended to fill up. This last experiment was formerly much used for medical purposes, the glass in this case taking the name of *cupping-glass.*

83. Pumps.—Here is a little ear-syringe, full of water. I dip it vertically into the basin, and empty it by pushing down the rod. Then I slowly draw up the rod again (Fig. 121): what is the result?—"*The water rises in the syringe.*"—Why?—"*Because the piston fits well, and the atmospheric pressure exerts itself on the surface of the water in the basin.* This, also, is on the same principle as the barometer."—And how far could the water thus rise in the syringe? —"To the top."—And if the syringe were several yards long? —"Still to the top, *unless the syringe were longer than* 33.8 *feet, in which case the atmospheric pressure would not be strong enough.*"

FIG. 121.—The water in the basin under the atmospheric pressure rises in the little ear-syringe.

Quite right. Now, the whole theory of PUMPS is contained in what we have just seen. True, there are many kinds of pumps, and their action seems somewhat complicated; in reality, however, it is simpler than it looks, for all pumps are merely syringes more or less improved and perfected.

Among these pumps, *one is very curious, and is used to exhaust from a vessel,* A (Fig. 122), *not water, but* AIR. This is called the *air-pump,* or *pneumatic machine,* and with its help very curious experiments can be made.

What name do doctors give to the glass for this operation? Why can we draw up water with a syringe? What is the greatest length a syringe could have? What is the use of pneumatic machines?

But before leaving physics I have something more to say to you.

84. Level of Liquids.—Let us return to our water-cask in the garden, which you remember we left half full of water. I fix to the tap with a bit of gutta-percha tube the long

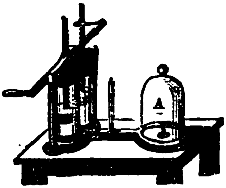

Fig. 122.—Air-pumps serve to exhaust from a vessel, A, not water, but *air*.

Fig. 123.—The water stops at A, at just the same level as in the cask.

glass tube (Fig. 123) with which we made a barometer, and which this time I have opened at both ends. Now,

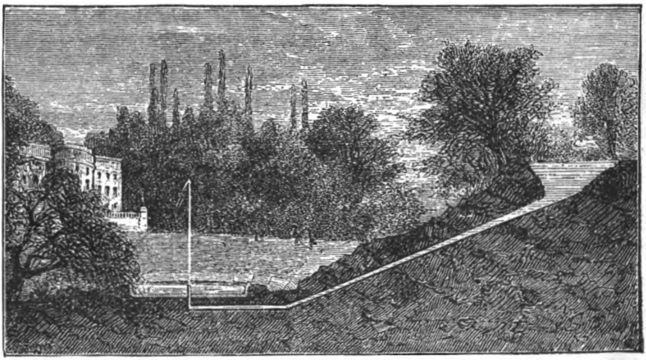

Fig. 124.—The water rises nearly to the height of the water in the reservoir B.

while I hold the tube vertically alongside the cask I shall open the tap. What will the water do?—"It will rise in the tube."—How high?—"I think it *ought to rise to the same*

If a tube be put in communication with a cask full of water, and then be held vertically, what will take place?

height as that in the water-cask."—Very good. See, the tap is open, and the water rushes into the tube: it stops at A, exactly *the same height as the water in the cask*, or, as it is called, *on a level with it.*

Thus water remains at the same level in all vessels communicating with one another. This level is exactly horizontal, and the plumb-line, which is vertical, falls perpendicularly upon it.

85. Fountains.—It is to reach the level of the reservoir R (Fig. 124), placed on the little hill, that the water springs out of the fountain in our neighbor's garden. It cannot, however, quite reach the height of the reservoir, because the air offers a certain resistance; but if a tube were placed upon the mouth of the fountain the water would rise exactly to the proper level, as it did in the tube fastened to the tap of our water-cask.

SUMMARY.—WEIGHT, OR GRAVITATION.

1. Gravitation, or Falling of Bodies (p. 68).—All bodies fall with equal rapidity.

2. When apparent differences exist, they are owing to the resistance of air.

3. The greater the length of time a body falls, the more rapidly does it pass through space.

4. A body allowed to fall always follows a straight line, called the VERTICAL, which is perpendicular to the surface of water.

5. The *plumb-line* shows the VERTICAL direction.

6. The WEIGHT of a body is the pressure it exerts when kept from falling.

7. Density (p. 71).—The DENSITY of a body is the weight of a given volume of that body as compared to the weight of a like volume of water.

8. The density of water, then, is said to be 1.

9. A given volume of mercury weighs 13.6 times as much as an equal volume of water: its density, then, is 13.6.

10. A given volume of iron weighs 7.8 times as much as an equal volume of water: its density, then, is 7.8.

11. A given volume of ether weighs 0.7, taking water as the standard: its density, then, is 0.7.

12. In order to ascertain the *weight* of bodies, balances or scales are used.

13. In order to ascertain the *density* of a body, the weight of the body must be divided by the weight of an equal volume of water.

Mention an application of the power possessed by water of finding the same level in conduits that communicate with one another.

14. The density of a body diminishes when its temperature is raised, because the body expands.

15. Pressure of Liquids (p. 76).—The *pressure* a liquid exerts on the bottom of a vessel depends altogether on the DENSITY of the liquid and its HEIGHT in the vessel.

16. Whether a tube containing a liquid have an equal diameter from top to bottom, or be widened out like a funnel, the pressure on the bottom will remain unaltered so long as the size of the bottom remains unchanged.

17. A fish whose surface measures 6 square inches, swimming at the depth of 100 inches, supports, calculating by the above-mentioned law, a pressure equivalent to the weight of 600 cubic inches of water.

18. The reason why the fish is not crushed is, that it is equally pressed upon in all directions at once, and that the solids and liquids which compose its body are incompressible and consequently cannot be crushed.

19. Pressure of Air.—Barometer (p. 82).—Air weighs upon us just as water weighs upon the fish.

20. The pressure of the air can sustain a column of water 33.8 feet high.

21. For greater facility, mercury is used instead of water, mercury being 13.6 times as dense as water. The height of a column of mercury kept in equilibrium by atmospheric pressure will, then, be 33.8 divided by 13.6, or 2 feet 6 inches. *Barometers* are thus made.

22. The height of the column of mercury diminishes if it is carried to the summit of some mountain or taken up in a balloon.

23. It is because of atmospheric pressure that liquids rise in pumps, siphons, etc.

24. Communicating Vessels (p. 91).—In vessels that communicate with one another, the water stands at the same level in all the vessels.

25. It is in virtue of this principle that the water of a reservoir in an elevated position, after having descended, rises again to its former level, be it in the form of a fountain or water in a pipe.

SUBJECTS FOR COMPOSITION.

1st Composition (pp. 9, 10).—The three states of bodies. The three states of water, of zinc. Are gases easily compressed? Application to air. Can liquids and solids be easily compressed?

2d Composition (pp. 10, 11).—Evaporation. Ebullition. Distillation.

3d Composition (pp. 13–15).—Give an example of the expansion of solids under the influence of heat. Liquids. Gases. Exception in the case of water.

4th Composition (p. 16).—Construction of thermometers.

5th Composition (pp. 20, 21).—Wood, charcoal, air, bad conductors of heat. Why our clothing protects us from cold. Why the handles of tools that are put into the fire are surrounded by wood.

6th Composition (pp. 23, 24).—Force of the steam of boiling water. Application of this force to machinery.

7th Composition (pp. 26–29).—Velocity of light. Reflection upon mirrors. Apparent breaking of bodies immersed in water.

8th Composition (pp. 30–34).—Concave lenses, convex lenses. Focus

of a lens. Microscopes. Spy-glasses. Spectacles for near-sighted people, spectacles for long-sighted persons.

9th Composition (pp. 35, 36).—Dispersion of light. Solar spectrum. Why the paper of your copy-book is white. Why ink is black. Why a rose is red.

10th Composition (pp. 38–41).—Vibration of bodies. Air a propagator of sound. Rapidity of sound travelling through air. Do liquids and solids transmit sound? Echo.

11th Composition (pp. 43, 44).—Stringed instruments. Wind instruments. Deep, grave sounds. Sharp, acute sounds. The A of the tuning-fork.

12th Composition (pp. 46–50).—Vitreous or positive electricity. Resinous or negative electricity. Attraction and repulsion. What is meant by *insulating bodies*.

13th Composition (pp. 51–55).—Power of points. Lightning-conductor. The two kinds of lightning.

14th Composition (pp. 56–59).—Electric batteries and piles. Effects of electric currents.

15th Composition (pp. 61–64).—Attraction of iron by the magnet. Magnetic attraction and repulsion. Mariner's compass. Natural magnets. Artificial magnets.

16th Composition (pp. 68–76).—Weight of bodies. Density. How to ascertain both weight and density.

17th Composition (pp. 76–82).—On what depends the pressure of liquids on the bottom of the containing vessel. Proofs.

18th Composition (pp. 82–85).—Atmospheric pressure. Measure of this pressure in water,—in mercury.

19th Composition (pp. 88–90).—Application of the principle of atmospheric pressure: a glass full of water is inverted in contact with a vessel of water and yet is not emptied; cupping-glasses, pumps.

20th Composition (pp. 91, 92).—Water remains at a common level in a series of vessels which communicate. Applications. Water-works, watering-pipes, distribution of water through towns.

V.—CHEMISTRY.

Fundamentals.

86. Differences between Physical and Chemical Phenomena.—I hope you have understood and kept in mind what a *chemical* phenomenon is, as compared with a *physical* phenomenon. In physics, one can always recover IN ITS FIRST FORM the body experimented upon. If heated, it cools; if electrified, it loses its electricity; if set in vibration, it comes to rest; if melted, it becomes solid again; if dissolved, it reappears when the liquid evaporates. This is far from being the case in CHEMISTRY: the bodies that have been experimented upon are totally changed; in fact, they give rise to OTHER BODIES, in which you could never directly recognize the first ones.

FIG. 125.—The sulphur that I burn *combines* with the oxygen of the air to form another body (chemical phenomenon).

See, here is some *sulphur*, or *brimstone*, as it is often called: it is a yellow, solid body, almost inodorous. I set it on fire (Fig. 125): it burns and disappears; but on coming near it you notice an intense acrid smell which makes you cough. This odor is caused by the escape of a *gas*. The sulphur exists in this colorless, odorous gas: you would never have supposed that, I am sure.

The sulphur in this gas is not alone: it is COMBINED, as it

What characterizes a *physical* phenomenon? What characterizes a *chemical* one? What takes place when you *burn* a piece of sulphur? Does the sulphur *alone* exist in this gas? Is that a physical phenomenon?

is called, with *another body*, which we shall shortly hear about. And the product of that *combination* is this gas.

This is the real distinction between chemistry and physics. In physics, we consider *only one body* at a time; in chemistry, there are always *several bodies* present.

Here is another bit of sulphur: let us put it on the blade of this old knife and heat it above the flame; we must carefully avoid letting it take fire. You see it becomes liquid; yet it is always sulphur, and *sulphur alone*. The heat becomes greater; the little drop of sulphur grows smaller and smaller, and in a short time will have entirely disappeared. The sulphur is volatilizing,—that is, changing to a gas,—but it is always sulphur, and *sulphur only*. The proof is, that when I hold a

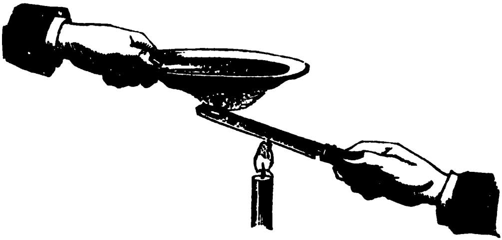

FIG. 126.—The sulphur that we cause to *evaporate* remains sulphur (physical phenomenon).

cold plate above it while it is thus volatilizing (Fig. 126), you see deposited there very small yellow grains: those grains are *pure sulphur*, what is called *flowers of sulphur:* the sulphur has been distilled as water would have been.

It is altogether different when I *set fire* to it. The gas thus formed IS NOT PURE SULPHUR; it would not become solid on a cold plate.

You noticed no smell when the sulphur volatilized, but this gas which comes from the flame brings tears to your eyes and irritates your throat.

In carefully *melting* sulphur, what takes place? How do you prove that what is produced is sulphur only? Is that a physical phenomenon?

87. Compound Bodies.—This gas, then, is not simply the vapor of sulphur. It is, as I have already told you, sulphur COMBINED with another body. This other body was in the air, and had it not been there the sulphur would not have given rise to that colorless and suffocating gas.

I said that the sulphur took from the air this other body with which it combined, and I shall prove this to you. I put some sulphured ends of matches upon a piece of wood that floats on the water in this vessel. I set the matches on fire, and immediately invert over all a glass shade (Fig. 127) and push it down into the water. See, the level of the water is at A in the globe, but you must look quickly, for it will not long remain there: it sinks to B on account of the heat. The matches die out; the air in the shade cools, and in a little time, when it is quite cold, you will see that the water will rise higher, as far as C, *much higher than it first was at* A. This clearly shows that the sulphur in burning has TAKEN a part of the air to make the gas of which we have been speaking.

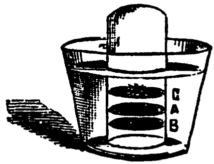

FIG. 127.—The level of the water rises to C, because the sulphur *combines* with the oxygen of the air in the jar.

This gas is, then, a COMPOUND BODY, composed of sulphur and a constituent of air: chemists call it *sulphurous oxide.*

In like manner, the green vitriol that we made at the commencement of our lessons on physics, with iron and oil of vitriol, is a COMPOUND body: it is *sulphate of iron.*

You must not imagine, however, that all COMPOUND bodies are thus produced artificially. Far from it: almost all the bodies by which we are surrounded in nature are COMPOUND bodies.

Let us repeat the experiment we made when speaking about *stones.* Here is a bit of chalk. I throw it into a glass of strong vinegar: water into which have been poured some drops of sulphuric acid (Fig. 128) would be still better. You

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What took place when the sulphur burned under the jar? Is this gas a *simple* body? What name do chemists give it? Show that the sulphate of iron is a *compound* body. Prove that chalk is a *compound* body.

will see in a moment that a great quantity of gas will escape from the chalk and rise to the surface: this gas existed in the chalk: it was there *combined* with something else,—with another body.

So there are natural compound bodies and artificial compound bodies. This may lead you to ask, Are there bodies that are not compound?

Yes, there are. Perhaps some day they also may be decomposed. But as yet science has not been able to do so, and those bodies are called SIMPLE BODIES, or ELEMENTS. Sulphur belongs to this class, iron also. Remember that; but you must also keep in mind that the term *simple body* merely signifies *a body which cannot be decomposed.*

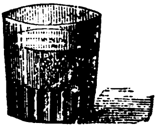

FIG. 128.—This gas which escapes (carbonic acid) existed in the piece of chalk.

Thus, on the one hand, *to decompose compound bodies and extract from them simple bodies*, and, on the other hand, *to combine simple bodies and therewith make compound bodies*, is the double work chemistry undertakes.

By DECOMPOSITION we acquire a knowledge of the real nature of bodies around us; by COMBINATION new bodies are produced which are most serviceable to mankind. You can easily form an idea of the uses and the interest of such a science.

88. Simple Bodies.—As I have just told you, sulphur and iron are SIMPLE bodies. There are many others: seventy simple bodies are known at the present day.

Some are SOLID, and they are the most numerous. Gold, silver, iron, copper, zinc, and *metals* in general are simple bodies; some other solids, also, that are not metals, such as sulphur, carbon, phosphorus, and arsenic.

There are two LIQUIDS, with one of which you are already well acquainted: it is mercury, which, although liquid, is a metal.

What name has been given to those bodies that we are not able to decompose? Name some *simple* bodies. How many simple bodies are at present known? Among simple *solid* bodies name one well-known class. Give some examples. Name some simple solid bodies that are not metals. How many simple *liquid* bodies are there? Mention one.

Four are GASEOUS, but I need not mention their names at present, as they are quite unknown to you.

This seems to surprise you.—"Why, yes; for we know *air* well enough, and it is a gas. Everybody knows it, and it is called one of the four elements: certainly it is a simple body."—And *water* also, in that case?—"Water also, yes." —And the *earth* also?—"Oh, no; we know that the earth is not a simple body."—Well, let me tell you that the word *element* has led you astray, for neither air nor water is a simple body. Air is *a mixture* of two simple bodies; water is a *combination* of two simple bodies.

89. Differences between a Mixture and a Combination. —"What difference is there between a *mixture* and a *combination?*"—That can be easily explained, but I prefer giving you an example.

See, here are some very fine iron filings, and there are some flowers of sulphur. I mix both together, and shake and stir them carefully. You cannot at present distinguish the one

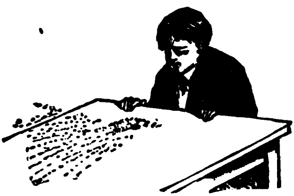

FIG. 129.—By gently blowing you can separate the flowers of sulphur from the iron filings (mixture).

FIG. 130.—The magnet attracts all the filings and leaves the sulphur (mixture).

from the other, so well are they mixed; yet they are only MIXED. *The proof is that you can easily separate them.* You have only, for instance, to blow gently on them (Fig. 129); the sulphur, being by far the lighter, will be blown

How many *gaseous* bodies are there? What is air? What is water? Is there a mixture or a combination when I mix iron filings with flowers of sulphur? Prove that there is only a mixture.

away, while the iron will remain. Or you may employ a more scientific method: take your magnet and pass it slowly close to the mixture (Fig. 130); all the filings will be attracted, leaving only the sulphur. The two bodies have merely been MINGLED,—a phenomenon purely PHYSICAL.

On the contrary, let us put our sulphur and our filings in this broken vessel, adding a little warm water (Fig. 131). In a few minutes, as you see, a great movement takes place: the little mass grows hotter, swells up, and becomes blackish. *It now resembles neither sulphur nor iron.* The two simple bodies are not merely mingled as they were a short time ago: they are combined, and have formed a new body, which chemists call *sulphide of iron.* This time we have witnessed a CHEMICAL phenomenon.

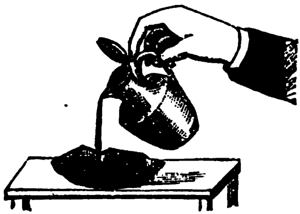

FIG. 131.—The sulphur and the iron have formed a new body (combination).

There is another great difference between a *mixture* and a *combination.*

I may MIX sulphur and iron in no matter what proportions, —I may add one, two, or three parts of sulphur, or more,— the mixture will simply be more or less rich in sulphur.

In a COMBINATION *this is impossible.* In order to have the combination of iron and sulphur I add 4 grains of sulphur to 7 grains of iron; the whole combined weighs, of course, 11 grains. That is not surprising. But had I put together 5 grains of sulphur and 7 grains of iron, the sulphide of iron resulting from the combination would notwithstanding have weighed only 11 grains: 1 *grain of sulphur would have remained unchanged,* pure sulphur as before. Likewise had I put 8 grains of iron, 1 grain of iron would have remained over, and would not have combined with the rest.

Give another proof. What takes place if some warm water is added to the mixture of iron and sulphur? Is there a *mixture* or a *combination?* What else characterizes mixture?

Thus, *combinations* are unlike *mixtures* in this, that they are not indefinite nor irregular; they cannot be obtained with all proportions of their elements. For instance, in the case of sulphide of iron, no matter what quantity of iron and sulphur you may mix together, the sulphide of iron obtained will always contain 4 of sulphur and 7 of iron. The *proportion* is, to use the terms employed by chemists, *definite*, or *determinate*.

I should like to see, now, whether you have properly understood me.

Here is a glass filled with vinegar and water in about equal proportions. Is this a *mixture* or a *combination?*—"It is a mixture, because one can add to the vinegar as much water as he chooses, it will always mix perfectly."—That is right: in other words, there is no definite proportion. What do you think, James? you do not seem convinced. —"What puzzles me is, that I do not know how I could separate the vinegar from the water as you separated the sulphur from the iron a little while ago. I should have thought that the vinegar and the water were combined."—Not so; for one distinctive character of the combination is that each of the bodies entering into it loses all its qualities, while the new body possesses new qualities. Recollect the sulphur and the iron on the one hand, and the sulphide of iron on the other. In this glass, can you not recognize the vinegar and the water? Has the liquid acquired qualities belonging neither to the vinegar nor to the water? Assuredly not. Then it is decidedly a *mixture*, and not a *combination*, and although it is not easy to separate the vinegar from the water, still that may be accomplished.

I shall now proceed to demonstrate that air is a MIXTURE of two gases, called *oxygen* and *nitrogen*, while water is a COMBINATION of two gases, *oxygen* and *hydrogen*. These may seem strange names; but I shall hereafter explain them to you.

What characterizes a *combination?* Give an example. Do vinegar and water form a mixture or a combination? Prove that vinegar and water form a mixture. What are the two gases that are mixed in the air? What are the two gases that are in combination in water?

Composition of Water.

We shall begin with water. For one reason, because it is the most curious. Is it not strange that this pretty, limpid *liquid* should not, in the first place, be a *simple body*, and, secondly, that it should be composed of two *gases?* Yet so it is.

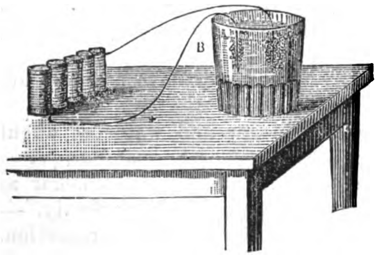

FIG. 132.—The two gases that you see rising to the surface of the water are *oxygen* and *hydrogen*.

90. Analysis by the Electric Pile.—You have not forgotten the rudimentary *electric pile* we made with pennies, and disks of cloth and zinc dipped in vinegar. I have made for this day's lesson several others like it, which I have united together so as to make use of the force of all of them at once (Fig. 132). I immerse the two *poles* in this glass of water, which has been slightly salted or *acidulated* with some sulphuric acid to allow it to *conduct* electricity with greater facility. After a few moments you will see tiny bubbles of gas forming on each pole and rising to the surface: you have doubtless already noticed also that these bubbles are not equally numerous at both poles. The two gases thus set at liberty are OXYGEN and HYDROGEN, the latter being the one that gives the greater number of bubbles.

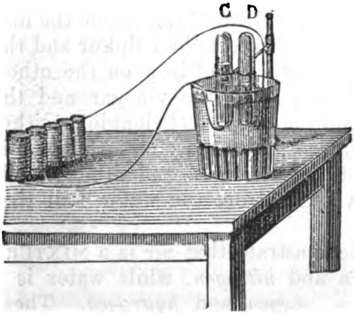

FIG. 133.—Two volumes of hydrogen are formed in D, against one volume of oxygen in C.

What takes place when the two poles of an electric pile are plunged into slightly salted or acidulated water? What are the names of the two gases that are given off?

Let us endeavor to catch some of each. For that purpose I take two small glass tubes C, D (Fig. 133), closed at one end: I fill both with water, and place one over each of the poles. The gas rises in each, but with greater rapidity in the tube D, which receives the hydrogen, than in the tube C, which receives the oxygen. It will be seen at a glance that the quantity of hydrogen discharged *is about double that of oxygen*, or, to speak more precisely, that there are *two volumes* of hydrogen for *one volume* of oxygen.

These gases are the result of the DECOMPOSITION OF WATER. If we had at our disposal a stronger pile, we could thus decompose all the water in our glass; and that would give us a large quantity of gas, I can assure you, for it has been ascertained that every cubic inch of water gives 1240 cubic inches of hydrogen and 620 cubic inches of oxygen.

91. Hydrogen.—While I have been speaking, the gases have almost filled up our little tubes, especially the one containing hydrogen, which I shall now withdraw from the water, stopping up the opening with my finger. Here it is. I hold it with the opening downward; and, in order that you may more plainly see what will take place, we shall go into a dark room. Watch closely, now, as I light a match (Fig. 134). I bring the lighted match close to the opening and take away my finger. Puff! a slight noise and a pretty pale flame, giving so faint a light that we should scarcely have seen it in the daylight.

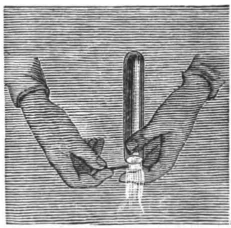

FIG. 134.—Puff! a slight noise and a little bluish flame. Hydrogen is, then, an *inflammable* and *explosive* gas.

Hydrogen is, then, as you see, an *inflammable* gas,—in other words a gas that can take fire. If instead of having a small tube we had used a large flask of it, we should have caused a *real*

In what proportions are oxygen and hydrogen found in water? What takes place when a lighted match is brought near a tube filled with hydrogen? What name is given to a gas that ignites in the air? What would have happened had the tube been larger?

explosion. Fortunately, there is no hydrogen in the air, or else there would be no means of kindling fire without blowing everything up.

Fig. 135.—***Fire-damp,*** **a near neighbor to hydrogen, produces, when inflamed, terrible explosions. It then combines with the oxygen of the air.**

Unfortunately, however, such accidents frequently happen in coal-mines, where a gas, *fire-damp*, a near neighbor to hydrogen, sometimes issues from the coal. By imprudently smoking or by opening their safety-lamps, miners sometimes

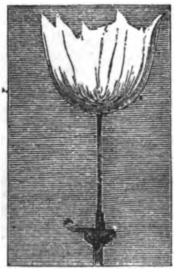

Fig. 136.—The gas for lighting, another neighbor to hydrogen, also presents dangers from explosion.

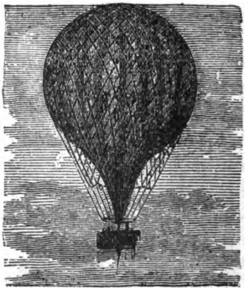

Fig. 137.—Balloons are filled with gas for lighting, which is three times lighter than air.

To what danger should we be exposed if hydrogen were in the air? To the presence of what gas are explosions in mines due? In consequence of what imprudence do these explosions result?

set fire to this gas, and fearful explosions are the result (Fig. 135). Another near relative of hydrogen is the *gas* which we burn, and with which our streets and houses are lighted (Fig. 136): it is made from coal, and, when conveyed in pipes from reservoirs, yields us incalculable services. It also is explosive. Its strong and disagreeable smell, however, betrays its presence and warns people of danger. On the contrary, *hydrogen* when *pure* has no smell whatever; neither has *fire-damp*, and this is one of its great dangers.

Hydrogen has still another characteristic. It is extremely light, ONLY $\frac{1}{14}$ AS HEAVY AS AIR. For this reason it was once much employed to *fill balloons* (Fig. 137). But, as it costs a great deal to prepare, COMMON COAL GAS is generally substituted for it. The latter is much heavier, since it is one-third as heavy as air; from this it follows that to be able to lift the same weight, the balloons must be much larger when filled with ordinary gas than when filled with pure hydrogen.

92. Oxygen.—Let us now look at our other tube C (Fig. 133), which is almost full by this time: as we have already said, this one contains OXYGEN. You see it has no appreciable color, no more than hydrogen or air. If I had enough to let you smell it, you would find that it is also without odor; but, as we possess only a very small quantity, we must economize it. I shall now show you its principal characteristic.

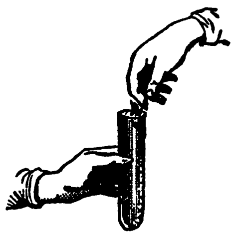

FIG. 138.—The match lights in the oxygen: this gas, then, keeps up *combustion*.

Pray light a match. Now blow it out, and hand it me quickly while the end is still red. I plunge it into the tube, and, wonderful to be told, *there it is lighted again*, and burning as before (Fig. 138).

Name another near neighbor of hydrogen. From what is the gas that we use for lighting streets made? What danger does it present? How do we know when there is an escape of gas? What is it that renders the presence of fire-damp and hydrogen so dangerous? Name a remarkable property of hydrogen. How has the extreme lightness of hydrogen been utilized? By what gas is it now replaced for filling balloons? How many times is ordinary coal-gas less heavy than air? What happens when a match, still red, is plunged into a tube filled with oxygen?

This is the characteristic action of oxygen. It *revives* and *accelerates* fire, or, as chemists say, it *supports combustion*. It is under the influence of oxygen, for that gas exists also in the atmosphere, that our fires blaze and give heat, and that our lamps give light. *Our very life depends on its presence,*—our life and that of all animals and plants, for every living thing breathes or wastes. We must, however, take things as they come, and we shall learn about this in another chapter.

You plainly see the great difference that exists between hydrogen and oxygen. Hydrogen *takes fire and burns*, but it cannot set fire to the red end of the match plunged into it; oxygen, on the contrary, rekindles the half-extinguished match, but *does not itself take fire.*

Chemists say that hydrogen is a COMBUSTIBLE body, like wood, coal, oil, etc., while oxygen is but a SUPPORTER of combustion.

93. Synthesis of Water.—Do you perfectly understand all this? I hope so. Now speak out: I see you wish to say something.

"You said that hydrogen takes fire, and afterwards you added that oxygen keeps the fire in. Is it, then, *oxygen that makes hydrogen burn?*"—Exactly so: *were there no oxygen in the air, we should try in vain to kindle hydrogen.*

If a flame were plunged into a vessel containing only hydrogen, great care being taken to avoid an explosion, or at least a blaze, in the introduction, the flame *would die out* for want of oxygen.—"Yes, but that is not what puzzles me most. When the hydrogen has burned up, what becomes of it?"

That, in fact, is the knotty point. Hydrogen in burning *combines* with oxygen, just as you saw the sulphur combine with the iron. After the combination there remained neither sulphur nor iron, but *sulphide of iron. Likewise, after the combination of hydrogen and oxygen, neither oxygen nor hy-*

What, then, is the principal property of oxygen? How does oxygen affect the existence of man, animals, and vegetables? What great difference is there between hydrogen and oxygen? By what terms do chemists express these particular properties? In what manner does oxygen affect the combustion of hydrogen? Prove that it is oxygen that makes hydrogen burn. What does hydrogen form in burning? What remains after the combination of hydrogen and oxygen?

drogen remains. What have we in their place? Who will answer that? Nobody? Think a little. We have DECOMPOSED water into *hydrogen* and *oxygen;* now we COMBINE *hydrogen* and *oxygen.* Ah! now you all find it out together. WATER! Of course; but you should have thought of that sooner.

Yes, WATER IS MADE again by burning hydrogen. And, as there is hydrogen in almost all the bodies we burn, water is formed when they burn. Look at this cold plate, which I hold over the flame of my spirit-lamp (Fig. 139). You see drops of water on it; don't be mistaken: this is not alcohol that has been distilled by the heat; taste it: it is merely water formed by the *combustion* of the hydrogen that existed in the spirit of wine.

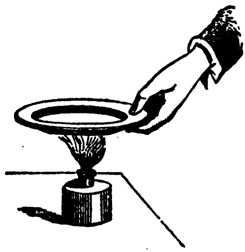

FIG. 139.—The water that condenses on the plate is the water formed by the combustion of the hydrogen that exists in the alcohol.

And now it is high time to tell you what the word *hydrogen* means. It comes from two Greek words, *hudor*, water, and *gennao*, to give birth to: it means, therefore, *a body that gives birth to water.*

Thus you see that the composition of water has been ascertained in two ways. First, by *decomposition,* under the influence of the electric pile, into two gases, one of which, the hydrogen, is double the volume of the other (oxygen). Secondly, by *recomposition,* the water being obtained by uniting, either by the aid of heat or by some other means, two volumes of hydrogen with one volume of oxygen. This splitting up of a compound into its simple bodies is called *analysis*, and the building up of a compound from its simple bodies is called *synthesis.*

Thus, if we put into a tube a mixture of hydrogen and oxygen, in the proportion of one volume of oxygen to two volumes

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Why is water formed in the combustion of bodies that we burn? Prove it by an experiment. What is the meaning of the word *hydrogen?* What do chemists call the decomposition of bodies into their simple elements? What is the recomposition of compound bodies called?

of hydrogen, and then set this on fire, water will be formed, and the hydrogen and oxygen will no longer exist. But if we had put three times more hydrogen than oxygen, what would have happened?—"There would have been too much *hydrogen, and some would have remained over.*"—How much? —"One portion."—You mean one *volume;* that is right. In like manner some oxygen would have remained unemployed had we put into the first mixture more than the necessary proportion.

In short, water is a *combination* of hydrogen and oxygen in *definite proportions*, as is the case with all chemical combinations.

Composition of Air.

94. Composition of Air.—Let us now pass to the study of *air*. I have already told you that OXYGEN enters into its composition, and we have made acquaintance with this gas in our lesson on water. You remember we saw it inflame hydrogen, thereby producing *water*, and it burned sulphur, thereby making *sulphurous oxide.*

But air is not composed solely of oxygen. The proof of this is, that the end of a match, newly blown out and still red, does not light again in the air, while we saw it do so in pure oxygen. In atmospheric air only about ONE-FIFTH part is oxygen; *the rest is a gas called nitrogen.*

95. Nitrogen.—Paul, how would you go to work were I to bid you prepare some nitrogen?—I mean, to separate it from the oxygen of the air?

"I should add hydrogen to the air, then set it on fire; the hydrogen would take up the oxygen, as you said, and form water, leaving the nitrogen alone."

Well imagined; very well indeed. But the plan would be very difficult to put into execution, and very expensive; yet it could be done if one had the necessary apparatus. You, James, have you found a method?

"I should set fire to some sulphur under a glass shade; the

What are the gases that enter into the composition of air? In what proportion are these two gases mixed?

sulphur would absorb the oxygen and set the nitrogen at liberty. It is the experiment you made a little while ago."

True. But that would not give you pure nitrogen: the sulphur would not burn up all the oxygen of the air. The experiment has, indeed, been made in that manner; but it is another body, *phosphorus*, not sulphur, that is usually employed.

96. Preparation of Nitrogen by Phosphorus.—I have a little bit of phosphorus here, so we will try. I am obliged to keep it under water, as you see, because it is rather dangerous, and sometimes takes fire by simple contact with the air. So, as quickly as possible, I put it on a bit of earthenware, this again on a piece of wood, the wood on the water, and a glass shade over the whole (Fig. 140).

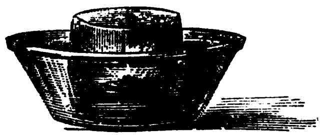

FIG. 140.—Nitrogen remains after the phosphorus by burning has taken up the oxygen of the air.

Let us now pass into the dark room. You see the phosphorus is luminous as soon as it is in air, and you all recognize the light it emits to be the same as that given by matches when rubbed on anything in the dark, for matches are made with phosphorus and other ingredients. You can see also that *phosphorus* well merits its name, for the word means *light-bearer*.

Now let us return to the school-room. Our bit of phosphorus, after having emitted a good deal of white smoke, all at once bursts into a flame. Had it not done so we should have been obliged to light it with a match. How pretty it is! Who would imagine that *such a thing could be extracted from the bones of animals?* Yet such is the case.

On account of the strong heat of the burning phosphorus, some air escapes by expansion from under the shade. See, now the flame dies away, the air cools, the water rises and stands still. *The gas remaining in the shade is* NITROGEN with a very little oxygen. If the phosphorus be left under

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How is phosphorus obtained?

the shade until it no longer glows in the dark, the very last traces of oxygen will have been exhausted. For this dim light is in reality *slow combustion*, while what we saw a little while ago was *rapid combustion.* You see there are different kinds of combustion; but they all have the same result.

97. Oxygenized Compounds of Phosphorus.—It is now the turn of nitrogen to be examined. But, before we set to work, will you tell me what has become of the phosphorus? —"*It has combined with the oxygen of the air*, as the sulphur did a little while ago."—Well, and what has it formed?— "As the sulphur forms sulphurous oxide, the phosphorus ought to form *phosphorous* oxide."—Not exactly: it forms *phosphoric* oxide.

"Please, what do the terminations *ic* and *ous* mean? You have already spoken about *sulphurous* oxide and *sulphuric* acid."

That is easily explained. Sulphur, phosphorus, and many other bodies can combine with oxygen in different proportions so as to form *several oxides and acids.* Hence the necessity of giving different names in order to recognize them, and yet these names must resemble one another, being given to different compounds of the same bodies. Thus, the termination *ous* is given to the oxide containing the *smallest proportion of oxygen*, and the termination *ic* to that containing the *greatest.*

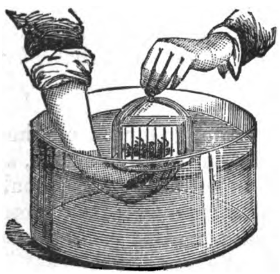

FIG. 141.—You see the mouse becomes agitated in the nitrogen, gasps and dies. The want of oxygen has killed it.

For instance, when the phosphorus burns brightly, it makes *phosphoric* oxide; when it burns slowly, as when it glows in the dark, it gives *phosphorous* oxide, less rich in oxygen.

98. Properties of Nitrogen.—And now to nitrogen. Here is a live mouse in a trap. I pass the whole rapidly under water into the nitrogen (Fig.

To what kind of acids do we give the termination *ous*? And the termination *ic*?

141) our experiment gave us. Immediately you see the mouse looks agitated, falls down and gasps: it is dead,—*asphyxiated*, as people call it. *It is not the nitrogen that has killed it: it is the want of oxygen.* Nitrogen is by no means a poison, for we breathe it in breathing the air in which we live, but it perfectly merits its *original* name *azote*, which means, *incapable of sustaining life* (*a*, which expresses negation, and *zoe*, life).

Thus, *life cannot exist in nitrogen.*

Nor can combustion exist in it. But how shall we prove this last affirmation? It is impossible to pass a lighted match through the water, as was done with the mouse: it would be extinguished before getting near the nitrogen. We must have some nitrogen in a tube, as we had the other gases a little time ago.

There is no great difficulty in this. Let us take our basin out into the court-yard and put it in the water-trough. We

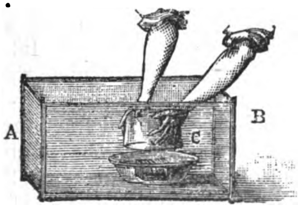

FIG. 142.—Hold the shade C full of nitrogen.

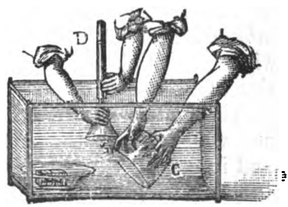

FIG. 143.—The nitrogen passes from the shade C into the funnel and fills the tube D.

will set it in the bottom of the basin, shade, mouse, cage, and all. Let one of you hold the shade containing the nitrogen and keep it in the water C (Fig. 142), mouth downward of course. I put a funnel in the little tube, fill with water both tube and funnel, and immerse the whole, the funnel undermost (Fig. 143). Now incline your shade slightly to one side, in the direction of the funnel. See, *the nitrogen passes into the funnel and fills the tube* D. There, the operation is successfully ended.

What happens when an animal is plunged into nitrogen? Is nitrogen a poison? Prove it. Why, then, did the mouse die?

Now, stopping up the opening of the tube with my finger, I take it out of the water, still holding it inverted. This time I shall put into it a well-lighted match (Fig. 144). See, *it goes out immediately.*

FIG. 144.—The match goes out in the nitrogen. So this gas does not support combustion.

That is enough, I suppose, to convince you that nitrogen does not support *combustion.*

99. Air is a Mixture, not a Combination.—As I told you, *nitrogen makes up about four-fifths of the air.* This is not the exact proportion: the exact numbers are 79.2 per cent. for nitrogen, and 20.8 per cent. for oxygen.

This makes 1 volume of oxygen for 3.80 volumes of nitrogen, and 1 part by weight of oxygen for 3.34 parts of nitrogen, for oxygen is a little heavier than nitrogen.

I, moreover, told you that air is simply a *mixture*, not a *combination*, and I am sure you will have no difficulty in following my explanation as to the reasoning by which we arrive at this conclusion.

In the first place, those complicated numbers and fractions differ widely from the *simplicity* of the proportions often found in combinations. You recollect, in water there are 2 volumes of hydrogen to 1 of oxygen, and in weight 1 of hydrogen to 8 of oxygen. In weight, again, for sulphide of iron, 4 of sulphur, 7 of iron; for sulphurous oxide, 1 of sulphur, 1 of oxygen; for sulphuric acid, 1 of sulphur, 2 of oxygen; for phosphorous acid, 2 of phosphorus, 3 of oxygen. In a word, as I have already said, in all COMBINATIONS the component bodies are not only *in definite proportions*, but are often also *in simple ratio.* MIXTURES, on the contrary, have no fixed ratio whatever, and are sometimes exceedingly complicated.

Secondly, the composition of air can be altered with great ease. If, when the phosphorus was burning a little while ago, I had allowed it to fall into the water, the air remaining

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Is air a mixture or a combination? Why do you suppose it is a mixture?

under the shade would have been less rich in oxygen than common air, and the longer the experiment would have lasted the less oxygen would there have been. There are not, then, any *definite proportions* in the composition of air, as there are in chemical combinations.

Again, air has at the same time the properties of oxygen and those of nitrogen. It supports the combustion of bodies by the oxygen it contains, but with less energy on account of the influence of its nitrogen; whereas you know that in a combination, water, for instance, the distinctive properties of hydrogen as well as those of oxygen have disappeared.

So, once more I repeat, air is only a *mixture*, and in no sense a *combination.*

Now we are beginning to see a little into chemistry, since we have learned what *air* is and what *water* is, this being no easy matter. We also know about *oxygen*, *hydrogen*, and *nitrogen*, three of the four simple bodies found in a gaseous state. The fourth, by no means without interest and utility, is *chlorine;* but its study would encroach too much on our time.

But we must not boast about what we have learned. How many bodies yet remain unknown to us!—not only simple bodies, but also compound bodies, composed of two, three, four, or more simple bodies! We could never think of learning about all these, nor could we even pass in review an insignificant part of them. Notwithstanding, I have yet to tell you about several very interesting things, which you will find useful to you in many respects.

Carbon.

100. Carbon.—In the first place we will occupy ourselves with the study of *charcoal.* Charcoal is an impure form of *carbon.*

101. Composition of Vegetable Matter.—You are all aware that charcoal is derived from plants, from *wood* burned

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In what manner do the simple bodies act in a combination? In a mixture? Of the four simple gaseous bodies, which are the three known to you? What is charcoal? From what is it derived?

in a certain smothered manner. This shows, of course, that carbon exists in plants, since it is extracted from them.

Indeed, it exists in all their parts,—in their wood, their leaves, their flowers, etc. And you will no doubt be astonished to learn that carbon is there combined with hydrogen and oxygen. *It is these three bodies*, CARBON, HYDROGEN, and OXYGEN, *that when united form almost all kinds of vegetable matter.*

I have here a bit of sugar, a substance derived from a plant. I put it on this red-hot shovel (Fig. 145), but prevent it from burning with a flame; in a short time there remains nothing but very pure and black carbon. If, while it is burning, I hold a cold plate (Fig. 146) above it, you will see water con-

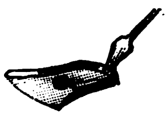

FIG. 145 —On the red-hot shovel the sugar leaves only a very pure black carbon.

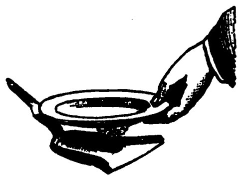

FIG. 146.—The water produced by the combination of oxygen and hydrogen of the sugar condenses on the plate.

dense on the plate. This water is produced by the combination of *the oxygen and the hydrogen of the sugar.*

Starch, gum arabic, alcohol, oils, and almost all substances of vegetable origin, will give the same result.

See what a variety of forms nature gives to these THREE SIMPLE BODIES, carbon, hydrogen, and oxygen.

102. Composition of Animal Matter.—CARBON exists also in the different parts of the BODIES of animals. What is known under the name of *animal black* is a *charcoal*, obtained by heating bones in close vessels.

In *animal fat*, also, hydrogen and oxygen are combined

What are the three bodies that form vegetable matter? What becomes of a piece of sugar on a red-hot shovel when it is prevented from catching fire? How do you prove that the sugar contains something else besides carbon? Of what is starch composed? Gum arabic? Alcohol? Oils? Where else is carbon found? What is animal black? What is the composition of animal fat?

with carbon just as in vegetable oil. In all the parts of the body, such as the flesh, the brain, etc., except in the fat, these constituents are found in combination with nitrogen. *And it is with these four simple bodies variously combined that all the different constituents of animal bodies are formed.*

Three are, as we have seen, gaseous; the fourth, *carbon*, is a solid body.

103. Various Forms of Carbon.—And now let us examine carbon itself. It enters, as we have said, into the composition of *wood, charcoal, and animal black.* Do any of you remember to have met with it under any other form?—"Yes. *Coal and coke.*"—Ah! is coke the same thing as coal?—"No; coal is greasy and shiny, while coke is dull-looking and quite dry."—Yes, those are obvious differences; but do you remember nothing more important? As some of you live in towns where the streets are lighted with gas, you can perhaps tell me the difference between coal and coke.—"Yes; *coke is that which remains when the gas that lights the streets has been taken from the coal.*"

Quite right: when the coal is sufficiently heated, the gas is set at liberty, and along with it many other things, *for it is marvellous what can be extracted from coal,*—rich colors, delicate perfumes, nearly a hundred useful substances, and among them flavors for sweetmeats. So you see coal is not pure carbon, far from it; *but that which remains after coal has been heated, that is to say, coke, is almost pure carbon.*

Carbon is found under still other forms. The *black lead*, as it is improperly called, of which your pencils are made, is almost pure carbon. It is found in certain mines, and is called also *plumbago* and *graphite.*

But what is most curious is that the DIAMOND IS PURE CARBON. I mentioned this fact when speaking about different crystals. Yes, it is quite true that the beautiful stone, so brilliant, so transparent, so hard that it can cut or engrave anything, however hard, *has the same chemical composition*

What is the fourth body that enters into the composition of the flesh and the brain? Of the four simple bodies that form the bodies of animals, which three are gaseous? Which is the solid body? What do we obtain from coal? What remains after the gas has been extracted from coal? Name another form of carbon. What is the diamond?

as the ugly bits of coal, black and friable, sold in cart-loads for a comparatively small sum. You cannot believe such a thing, and your very eyes demand proofs of it. Well, I am prepared to give you these proofs.

104. Products of the Combustion of Carbon.—First, if a diamond be heated to a high temperature, it will swell out, and be transformed into a substance very similar to coke. This, however, might pass for mere external resemblance, and might be disdained as proof of chemical identity.

Here is a lump of coal. I put it on the fire. It reddens, burns away, and disappears, as you all know, leaving only a few cinders, which are merely impurities, and have nothing to do with carbon. The carbon has disappeared; it has burned. But what has become of it? for, as you know, nothing can be lost. In burning it *has combined with the oxygen of the air*, precisely as did the sulphur burned in a former experiment.

This combination can give rise, according to circumstances, to two sorts of gas.

When coal burns brightly and with strong heat, it forms CARBONIC ACID GAS, in which there are 3 parts of carbon for 8 parts of oxygen. *When it burns slowly and dimly, it forms* CARBONIC OXIDE, in which there are 3 parts of carbon for only 4 parts of oxygen.

In our fireplaces the coal in burning gives off a mixture of *carbonic acid gas* and *carbonic oxide*. The more draught the chimney gives, the brighter the fire burns, and the more active is the oxidation and the less carbonic oxide gas is produced.

You ought now to understand sufficiently the real chemical characters of carbon. You may burn coke, animal black, graphite (plumbago), or diamond, you will always have carbonic acid or carbonic oxide gas given off, according to the greater or less energy of the combustion.

And you will have, at least in the case of graphite (plumbago) and of the diamond, for these will not leave even

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Give a proof that the diamond is carbon. What gas is formed when coal burns brightly and quickly? What when it burns slowly? What does coal form while burning in our fireplaces? What happens when the fire burns brightly? Give a second proof that the diamond is pure carbon.

cinders, only a gas as the product of the combustion. Thus *all these bodies are carbon*, pure carbon, especially *graphite* and *diamonds.*

Now the *carbonic oxide* and *carbonic acid gases* formed in our fireplaces and stoves, or emitted by our lamps and candles, merit our attention.

105. Carbonic Oxide Gas.—Let us begin with the *carbonic oxide.* It is a colorless and inodorous gas when mingled with the air, and this is very much to be regretted, *for it is a most deadly poison.* A *thousandth part* of this gas in the air suffices to cause death in a very short time; a *ten-thousandth part* is enough to give a violent HEADACHE. You see how important it is for our health and even for our life *that the products of combustion should escape easily and with certainty from our dwellings* by the chimneys. The small stoves in which charcoal is often burned give out a large proportion of CARBONIC OXIDE, and hence occasion *headaches, pallor*, and *even dangerous illnesses.*

106. Carbonic Acid Gas.—Oxide of carbon can be set on fire and burned like hydrogen: it then forms what?—"*Carbonic acid.*"—Exactly so: the oxide of carbon combines in a new proportion with oxygen from the air. It burns with a pretty pale-blue flame, which you can see dancing up and down on the charcoal I have lighted in this little stove. Unfortunately, a great part of the carbonic oxide is not consumed, but escapes into the air.

In short, carbonic acid gas can be formed in two ways during combustion: either in a single operation by direct combination of the carbon with a considerable quantity of oxygen, or by the combustion of oxide of carbon that has been previously formed. All this is continually going on in our fireplaces, and this it is that gives us heat.

Carbonic acid gas is also colorless and has little if any odor. It is much less dangerous than carbonic oxide, and it becomes seriously so only when there is about 2 per cent. in

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What do you know of carbonic oxide gas? What effect is produced by the one-thousandth part of oxide of carbon in the air? By the ten-thousandth part? How, then, ought our fires and chimneys to be arranged? What gas escapes from charcoal stoves? What precaution is it necessary to take? What quantity of carbonic acid in the air is seriously dangerous?

the air. But people should, notwithstanding, be very cautious with carbonic acid, for two reasons.

In the first place, it would not be healthy for a person to remain in a place where the air contained one-tenth of one per cent. of carbonic acid; but this is not all. When there is carbonic acid in a room, it is not because some chemist has brought it there to mix with the air of the room. Of course not: it was formed there. And at the expense of what? Undoubtedly at the expense of the *oxygen of the air.*

Now, carbonic acid gas is so composed that it contains a volume of oxygen equal to its own volume. Then, if there exist in a room one per cent. of carbonic acid, one per cent. of oxygen must be wanting: instead of the 21 per cent. that ought to be *present* in wholesome air, only 20 per cent. remains. You understand that a person under such conditions incurs double danger: first, in breathing the air poisoned by the carbonic acid; secondly, in running the risk of being asphyxiated for want of oxygen. This might easily happen to us without using charcoal or anything of the kind; all that we should have to do would be to shut everything very close, and all of us remain here in the school-room. How so? you may ask. Ah! we also *absorb oxygen and give back carbonic acid.* Our body BURNS in its interior, just as the bit of wood burns in the chimney, but it burns very slowly, and yet without forming carbonic oxide. But here we enter upon another territory. We shall learn about this when we come to study *animal physiology.*

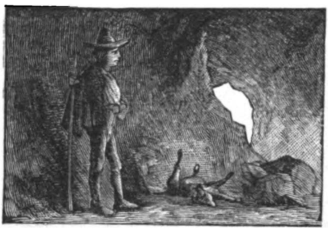

FIG. 147.—Carbonic acid spread on the ground kills the dog, but does not act upon the man.

Carbonic acid gas is formed not only in our fireplaces and in living bodies. In certain countries it oozes abundantly out of the

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Compare it with oxide of carbon. At the expense of what is carbonic acid formed in a room where we breathe? What happens when there is one per cent. of carbonic acid in a room? What takes place during breathing?

earth. In the island of Java there is said to be a valley in which the soil emits such quantities that nothing can live within its bounds, and the very birds that ventûre to fly through it fall down overpowered and die. Near Naples, at Pozzuolo, there is a grotto (Fig. 147) in which a man can walk without danger, but into which a dog cannot enter without being asphyxiated by the carbonic acid that escapes from the soil. You ask why there is danger for a dog while a man is in safety. It is because the carbonic acid, being heavier than the air, remains low down near the ground.

Carbonic acid is also formed *during the fermentation of beer or of wine.* Hence the danger in making wine or beer in insufficiently ventilated places (Fig. 148).

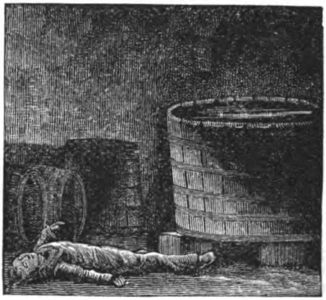

FIG. 148.—Carbonic acid is formed in the fermentation of beer and wine.

After all this you will not be surprised to learn that there exists a little carbonic acid gas in pure air, in variable proportions, but always less than one part per thousand.

107. Carbonate of Lime.—Carbonic acid is, nevertheless, very frequently met with in nature, not free, however, but in *a combined state.*

I shall again have recourse to an experiment which has already proved useful to us on more than one occasion. Here is a bit of *limestone.* I put it in a glass and pour strong vinegar (Fig. 149) over it. You see it gives off bubbles of gas: *this gas is carbonic acid that the vinegar has set free.*

With what was the carbonic acid united? With the

Name some examples of the natural formation of carbonic acid. Under what other circumstances is carbonic acid formed? In what proportion is carbonic acid mixed in the air? Under what form is carbonic acid frequently found in nature? How do you prove that a calcareous stone contains carbonic acid?

lime; we have already learned that. If we had submitted the stone to a very strong heat for a length of time, the carbonic acid would have been set free, and the lime only would have remained, and therefore had it subsequently been put into vinegar no effervescence would have ensued.

FIG. 149.—From the calcareous stone escapes the carbonic acid which the vinegar had set free.

Chemists give to this calcareous substance the name *carbonate of lime*, which name indicates that *carbonic acid* and *lime* enter into its composition.

108. Synthesis of Carbonate of Lime.—Before leaving this subject, let us do as we did when studying water. We decomposed carbonate of lime by analysis, let us re-form it by synthesis.

FIG. 150.—The liquid that passes is limpid; still there is in it a little dissolved lime: it is lime-water.

There is nothing easier. I shall throw into a glass of water this little bit of lime, but I must take care, for it is lime recently made, *quick-lime* as it is called, and will impart considerable heat to the water. There, now, it is quiet and a part of the lime is dissolved. In order to separate this liquid part from what has settled down at the bottom of the glass, I shall filter it through some blotting-paper folded and placed in the funnel (Fig. 150). See how limpid it is as it runs through. Yet it contains lime in solution, and is what is called *lime-water*.

Now, in order to form carbonate of lime with this lime-water, what must we add to it?—"Carbonic acid."—Yes, but how could you do so?—"Well, I should take a pair of bellows and go and fill the bellows over the fireplace where the carbonic acid escapes from the combustion of the coal, then I would blow the contents of the bellows into the glass of lime-water."—Very good; very well thought of. But if you had no bellows, or if there were no fire, what would you do then?—"I have heard papa say there is

What name do chemists give to the combination of carbonic acid and lime?

carbonic acid in soda-water: I should just put soda-water into the lime-water."—Very true, there is carbonic acid in soda-water; and it is this gas that escapes when the bottle is opened. Ah! I see George has found something. What is it?—"Why, *since we ourselves produce carbonic acid* by *breathing, we should only have to blow our own breath into the lime-water:* that is easy enough."—Well answered; as you say, it is easy enough: the difficulty was to find the idea. And to reward you for your sharpness, I shall beg you to make the experiment yourself. Blow into the water through this straw (Fig. 151). Do you see how the water becomes turbid and thick-looking as if you had poured milk into it? This change is produced by the presence of CARBONATE OF LIME *formed by the lime in solution in the water and the carbonic acid* passed into it. This, then, is the *synthesis* of carbonate of lime.

FIG. 151.—The lime-water becomes turbid. It is because George in blowing into it carbonic acid formed carbonate of lime.

Let it settle down in the glass. At the end of the lesson we shall pour off the water; and then if we add some vinegar we shall see the carbonic acid furnished by George's lungs rising in bubbles to escape.

Oxides, Acids, and Salts.

109. But we have not yet finished with *carbonate of lime;* it will still afford us several important facts. As we have already seen, *carbonic acid and lime* enter into its composition. Carbonic acid gas we know is composed of 3 parts of carbon to 8 parts of oxygen. But what is lime? Is it a simple body? No, it is a compound body. Composed of what? Of OXYGEN again, and a simple body, a metal

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What happened when George blew into the lime-water? What name do chemists give to this recomposition of carbonate of lime? Of what is lime composed?

which it is very difficult to separate from the oxygen; this metal is called CALCIUM. Chemists say that lime is an *oxide of calcium.*

110. Metallic Oxides.—*Oxygen combines in like manner with all metals, thus forming* OXIDES. The readiness with which this combination takes place depends upon the nature of the metal; but it always does take place. If we had at our disposal some *calcium*, and were to expose it to the air, it would rapidly absorb oxygen, so as to become *lime.* Further than this, were it thrown into water, it would at once decompose the water, so as to take hold of the *oxygen*, expelling the hydrogen. This, then, is a metal which is easily oxidized.

Let us now cast a glance at IRON. As you well know, it can be left exposed to the air without fear of immediate injury. Yet, after a considerable time if the weather be dry, or in a few days if the weather be damp, its surface will undergo an alteration: it will RUST, or, as the chemist would say, will *oxidize. And in reality it absorbs oxygen from the surrounding air*, and the reddish powder that you all know so well is the result of that combination. Rust is, then, an *oxide of iron.*

Now let us look at COPPER. It can remain still longer than iron in contact with the atmosphere without undergoing alteration. Nevertheless, in time, under the influence of damp it also will *oxidize*, and will form a greenish body called *verdigris.* This verdigris is *an oxide of copper.*

We must now study MERCURY, that silvery *liquid* metal which I showed you when explaining the construction of barometers. We might leave it for any length of time in contact with air and yet detect no alteration. But were we to make it boil for some hours we should see its surface covered with a reddish powder, which would be *oxide of mercury.*

Lastly, SILVER *never oxidizes by contact with the air*, it rusts neither by cold nor by heat; nor does GOLD. Chemists, however, are able, and that without difficulty, although

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What name do chemists give to lime? What combination does oxygen form with other metals? What would happen to calcium if exposed to the air? How does calcium act in water? What happens to iron when exposed to the air? What is *rust?* What effect has damp air upon copper? What is verdigris? What is mercury? How can mercury be oxidized? By what property are gold and silver distinguished?

by indirect means, to obtain *oxide of gold* and *oxide of silver*.

This more or less rapid oxidation by the simple contact of air explains *why some metals are very frequently found in the earth in their* NATURAL STATE, *while others are always found in the state of oxides*, or in still more complicated combinations.

Thus, gold, silver, platinum, mercury, and copper are frequently found in the soil in a metallic or *native* state; that is to say, *pure*. *Native iron*, on the contrary, is very rare. Zinc, tin, lead, are always combined either with *oxygen* or with *sulphur;* but, as they neither oxidize very rapidly nor have a great affinity for oxygen, it is not very difficult to remove from them the oxygen with which they are naturally united.

It is, of course, very different with metals that have a great affinity for oxygen,—*calcium*, for instance. They are never found in a native state. And it is, moreover, extremely difficult to remove their oxygen and bring them to a metallic form. Even the hottest fire fails to bring about this result.

From time immemorial, *lime* has been known; but not until the present century was *calcium* separated from it: this was obtained by the decomposition of lime under the influence of a strong electric pile. In like manner *potassium* has been obtained from *potash*, *sodium* from *soda*, *magnesium* from *magnesia*, substances with which chemists have been acquainted for many a day.

In short, in one way or another, with more or less difficulty, all *metals* combine with oxygen, and so form *oxides*.

111. Non-Metallic Oxides.—But OXYGEN also combines, as we have already seen, with bodies which have neither the weight, the brilliancy, nor the other qualities of metal. Thus we learned that it combines with CARBON and forms *carbonic oxide gas* and *carbonic acid gas*.

Name some metals that are frequently found in the earth in the *native* state. Mention a metal that is rarely found in the native state. In what condition are zinc, tin, and lead found? What happens to metals that have a strong affinity for oxygen? Name some metals which it has only lately been possible to extract from their oxides. To sum up: what do all metals form in combining with oxygen? Does oxygen combine with non-metals? What compounds does it form with carbon?

With SULPHUR it forms *sulphurous oxide* and *sulphuric acid.*

With PHOSPHORUS it forms *phosphorous acid* and *phosphoric acid.*

I might tell you, also, that it combines with NITROGEN in a real combination,—not a mixture, as in air,—thus forming several *oxides*, the most important of which yield *nitrous acid* and *nitric acid*, sold under the name of *aqua-fortis*. This last-named is extremely dangerous, burning terribly. The slightest touch of it stains the fingers with ugly yellow spots.

112. Acids, Bases.—In most cases the compounds of oxygen with metals are called *oxides* or *bases.*

Thus, potash, soda, lime, magnesia, the oxides of iron, copper, etc., are bases.

The compounds that oxygen forms with non-metallic bodies are generally called acids after they have combined with water: we have already learned about carbonic acid, nitric acid, sulphuric acid, etc.

But you must, moreover, know that some bodies are called acids and bases although they contain no oxygen.

For instance, volatile alkali, or hartshorn, called in chemical language ammonia, is a compound of nitrogen and hydrogen, yet it is a base.

Again, hydrochloric acid is a compound of chlorine and hydrogen only; and sulphydric acid (the compound which gives the disagreeable smell to rotten eggs) contains only sulphur and hydrogen.

Chemists have not selected these names without strong reasons, but it would be almost impossible for me to explain clearly to you what those reasons are.

I must acquaint you with another character which causes one body to be called acid and another alkaline.

I add to this glassful of water a few drops of ammonia. I then dip in it this slip of blue paper which has been colored by litmus: the paper remains of the same color as before.

In this other glass I have added to the water some drops

What compounds does oxygen form with sulphur? With phosphorus? With nitrogen? What do you know of nitric acid, or aqua-fortis?

of sulphuric acid. I dip into this glass, also, a similar little slip of blue paper. See, it has immediately become red. If I now replunge it into the glass containing the ammonia water, it will resume its blue color.

Hence it is said that acid substances redden the litmus dye, while alkaline substances bring back the blue color. All colors obtained from plants are modified in like manner by acids or by alkaline substances.

I shall now show you a very curious experiment. I take our pile, a glassful of water, and two tubes, and I arrange the whole as we did when we decomposed the water. (See p. 102, Fig. 133.) Only I add to the water some drops of tincture of litmus, which gives a blue color, and a small quantity of a body called sulphate of soda.

There, the electric current passes. You see that in the tube in contact with the positive pole, from which oxygen is given off, the water becomes red; in the other tube, on the contrary, the water remains blue.

Therefore, when a body is decomposed by means of an electric current, *the acid goes to the positive pole, and the base, or alkaline constituent, to the negative pole.* Bodies composed of an acid and a base are called SALTS.

There exist of these, as you may readily imagine, a great number, since about fifty metals are known to be capable of giving bases. I shall mention a few of the more important.

In the first place, there are *carbonates:* carbonate of lime, which has already so often come under our notice; carbonate of potash, which is to be found abundantly in wood-ashes; carbonate of soda, which is used in a crystalline state and is ordinary washing-soda. Carbonates are easily recognizable by the fact that, from whatever metal they are derived, their carbonic acid always escapes in a gaseous form when they are decomposed.

Then we have the *nitrates.* The most interesting of these is nitrate of potash, or saltpetre, which is to be found on old damp walls. It is used in the manufacture of gunpowder, in which it is mixed with sulphur and charcoal.

What name is given to the compound of an *acid* and an *oxide* or *base*?

Several sulphates have considerable practical interest. For instance, *sulphate of lime*, otherwise called plaster of Paris; sulphate of sodium; sulphate of magnesium, much used for medicinal purposes under the name of Epsom salts; sulphate of iron (green vitriol), and sulphate of copper (blue vitriol).

Among *phosphates*, phosphate of lime is one of the constituents of bone, and is much used in agriculture.

The *silicates* hold an important place in nature: silicious stones (slate, clay, granite, quartz) are composed of silicates.

Another category of salts is formed by acids that contain no oxygen. Those best known are the *chlorides* and the *sulphides*.

Sea-salt is a chloride of sodium; that is to say, a compound of chlorine and of sodium: two bodies only.

You can see the difference between these and the other salts which we considered a little while ago, such as, for example, the carbonate of lime, in which there are, 1, carbonic acid (carbon and oxygen), and, 2, lime (calcium and oxygen): in all, three bodies.

Metals generally used.—The most necessary of these is *iron*, an important peculiarity of which is its property of being welded or sticking together when strongly heated in the fire.

When brought to a very high temperature by means of an exceedingly intense fire, it becomes sometimes cast metal, sometimes steel.

You all know the many different uses made of iron and other much-employed metals, such as copper, lead, tin, zinc, silver, gold, mercury.

Under some circumstances, as you know, several are mixed together so as to form the alloys necessary for industrial usages: such are brass, which is an alloy of copper and zinc, and the bronzes, which are alloys of copper and tin in different proportions.

The greater number of the metals I first mentioned were known in ancient times. I have already told you that some, such as gold, are found in a pure state among sand or in rock, from which they are easily extracted. Others,

and these are the more numerous, exist as oxides, sulphides, or carbonates.

In these last two cases, they are roasted in contact with the air; the sulphur or carbonic acid escapes, and an oxide of the metal remains.

As for the oxides, they are mingled with the coals and subjected to intense heat. The coal takes hold of the oxygen of the metal, thereby forming carbonic acid and carbonic oxide, both of which escape, leaving the metal alone.

It is in this way that iron is treated in *blast-furnaces.*

Metals may be by various processes coated one upon another. A thin coating of gold or silver may be laid on any other metal, etc. This is called gilding or silvering. Wires are also coated in like manner, so as to prevent rust; cooking-utensils are lined with tin, so as to avoid the formation of verdigris, etc.

Many more interesting things I might tell you about metals had we time.

SUMMARY.—CHEMISTRY.

1. **Simple Bodies and Compound Bodies** (pp. 95–97).—Bodies that cannot be decomposed are called *simple bodies,* or *elements.*

2. *Compound bodies* are bodies in which there exist several simple bodies COMBINED.

3. Seventy simple bodies are known at the present day.

4. All metals belong to this class.

5. The greater number of simple bodies are *solids;* such are gold, silver, iron, copper, zinc, lead, tin, sulphur, carbon, phosphorus, and arsenic.

6. Two are *liquids,* one of which is mercury.

7. Four are *gaseous;* these are oxygen, hydrogen, nitrogen, and chlorine.

8. **Mixtures and Chemical Combinations** (p. 99).—There is a very great difference between a *mixture* and a *chemical combination.*

9. In a MIXTURE the nature of the bodies mixed together remains unaltered, and the mixture can be made in *any proportion whatever.* The phenomenon is purely *physical.*

10. In a CHEMICAL COMBINATION the nature of the bodies present is totally changed, and the union of those bodies takes place in simple and definite proportions.

11. Air is a *mixture;* water is a *combination.*

12. **Water** (p. 102).—Water is a *combination* of two gases, one called HYDROGEN, the other OXYGEN.

Water may be easily *decomposed* under the influence of the electric current: this decomposition gives one volume of oxygen for two volumes of hydrogen.

13. **Hydrogen** (p. 103).—Hydrogen is an inflammable gas.

14. If a mixture of *air* and *hydrogen* be set on fire, an EXPLOSION will ensue and water will be obtained.

15. This happens in coal-mines, where *fire-damp*, a near relative of hydrogen, escapes from the coal.

16. **Gas.**—The gas we burn is another relative of hydrogen: when it is mingled with air and set on fire there is the same kind of EXPLOSION.

17. Hydrogen is fourteen times lighter than atmospheric air. It might be used for aerostatic purposes; but, on account of the expense its preparation involves, common coal gas is used in its stead to fill balloons. *Illuminating gas* is about three times lighter than air.

18. **Oxygen** (p. 105).—OXYGEN keeps up COMBUSTION; in other words, it is oxygen that makes our fires burn and our lamps give light, etc.

19. It is OXYGEN ALSO THAT KEEPS UP OUR VERY LIFE, and along with our life that of all animals and plants.

20. **Air** (p. 108).—Air is a *mixture* of oxygen *and nitrogen* in the proportion of one-fifth oxygen to four-fifths nitrogen.

Pure nitrogen is obtained by causing phosphorus to absorb the oxygen of the air.

21. **Nitrogen** (p. 109).—Pure NITROGEN is incapable of keeping up combustion; even life is extinguished by it.

22. **Carbon** (p. 113).—CARBON, combined with hydrogen and oxygen, composes almost all vegetable matter.

23. Again, it is with oxygen and hydrogen that carbon is united in all *animal fat* as well as in vegetable oil.

24. In the flesh and in the brain the carbon is, moreover, accompanied by nitrogen.

25. *Animal black* is simply carbon obtained by the calcination of bones in closed vessels.

26. Thus, it is with *four simple bodies combined* (carbon, hydrogen, oxygen, and nitrogen) that nearly all substances which form the bodies of animals are constituted.

27. The COKE that remains when gas has been extracted from coal is almost pure carbon.

28. *Black lead*, or *graphite*, and DIAMONDS are other forms of carbon.

29. **Carbonic Oxide** (p. 117).—When charcoal, coal, or coke burns slowly it unites with oxygen and forms a gas called *carbonic oxide*.

30. Carbonic oxide is a VERY VIOLENT POISON. A thousandth part of this gas mingled with air suffices to kill rapidly.

31. In cooking-ranges heated with charcoal, and in stoves also, a great proportion of *carbonic oxide* is formed.

32. Hence the great importance of having chimneys draw properly, and the great danger of going to sleep in a room heated by a portable stove.

33. **Carbonic Acid** (p. 117).—When either coal or charcoal or other combustible burns briskly and well, it unites with the oxygen of the air and forms a gas, called CARBONIC ACID, which contains twice as much oxygen as carbonic oxide.

34. Carbonic acid, although much less dangerous than carbonic oxide, can, notwithstanding, occasion very serious illness, and even death.

35. Man, in the process of breathing, absorbs oxygen and gives back *carbonic acid.*

36. Carbonic acid is also formed in the fermentation of *beer* and *wine*. It is the carbonic acid given off that renders these fermentations so dangerous.

37. Carbonate of Lime (p. 119).—The carbonate of lime is a combination of carbonic acid gas and lime.

38. *Chalk* is carbonate of lime.

39. Oxides (p. 121).—Lime is an *oxide of calcium;* that is to say, a combination of *oxygen* with the metal *calcium.*

40. Oxygen combines in like manner with all metals, thereby forming *oxides.*

41. Iron *rusts* in damp air; rust is a combination of iron with the oxygen of the air: it is *oxide of iron.*

42. In damp air, copper becomes covered with a greenish substance called VERDIGRIS. This is a combination of copper with the oxygen of air, an *oxide of copper.*

43. Gold and silver *never* oxidize by mere exposure to air, and for this reason they are always found in the earth in a pure state, or, as it is called, in a *native* state.

44. Iron, zinc, tin, lead, on the contrary, are almost always combined either with oxygen or with sulphur.

45. Lime is an *oxide of calcium.*

Potash is an *oxide of potassium.*

Soda is an *oxide of sodium.*

Magnesia is an *oxide of magnesium.*

46. Acids, Bases. Salts (p. 124).—*Carbonic* acid, *sulphuric* acid (vitriol), *phosphoric* acid, *nitric* acid, commonly called *aqua-fortis,* and in general all the compounds of oxygen with non-metallic bodies, are *acids,* as their names show.

47. *Lime, potash, soda, and magnesia* are BASES.

48. The combination of an acid and a base is called a SALT. For instance, carbonate of lime (chalk) is a salt, composed of carbonic acid and oxide of calcium.

SUBJECTS FOR COMPOSITION.

1st Composition (p. 99.—Mixtures and combinations.

2d Composition (p. 102).—Composition of water. Analysis of water. by the electric current. Synthesis of water (p. 106).

3d Composition (p. 103).—Hydrogen, combustible and explosive body. Its weight relatively to that of air. Fire-damp. Gas that lights our cities.

4th Composition (p. 105).—Oxygen. The part it plays in combustion. Its presence in water, in air.

5th Composition (p. 108).—Air. Its composition. Nitrogen. Preparation of nitrogen with phosphorus. Properties of nitrogen (p. 110).

6th Composition (pp. 101, 112).—Water is a chemical combination, air is a mixture.

7th Composition (p. 113).—Carbon. Its presence in animal as well as in vegetable matter. Various forms of carbon.

8th Composition (p. 116).—Production of the combustion of carbon. Carbonic oxide. Carbonic acid.

9th Composition (pp. 119, 120).—Analysis of carbonate of lime. Synthesis.

10th Composition (p. 121).—Oxides. Salts. Acids.

PARTS VI. AND VII.

ANATOMY AND PHYSIOLOGY.

PREFACE.

BEFORE the English translation of the "First Steps in Scientific Knowledge" appeared, five hundred thousand copies of the original had been sold in France within three years. Immediately after the appearance of the first English edition a second was called for; and the American publishers feel confident that the success of the American edition will not be less than that of the foreign.

The American editor has made in the excellent translation of Madame Bert only such changes and additions as were necessary to Americanize the book, and to adapt it to the requirements of public and private schools as well as to home instruction in this country.

In the Anatomy and Physiology has been incorporated a translation of the chapter on Hygiene from the more elementary book prepared by M. Paul Bert to meet a change in the grading of primary instruction in France.

TABLE OF CONTENTS.

PART VI.—ANIMAL PHYSIOLOGY.

PART VII.—VEGETABLE PHYSIOLOGY.

ANATOMY AND PHYSIOLOGY.

VI.—ANIMAL PHYSIOLOGY.

1. It is undoubtedly a very interesting thing to learn the names of animals, plants, and stones, where and how they are found, how they resemble or differ from one another, what use we can make of them or how we are to guard ourselves from such as are harmful to us. It is very interesting to know how bodies fall by attraction, how light is reflected, how electricity is produced. But what is infinitely more interesting *still, is to know how we ourselves live*, and to learn the *history of the animals* that surround us, whose history is pretty nearly the same as our own. Physiology (from two Greek words, *physis*, nature, and *logos*, study) is the name given to the science that treats of these vital phenomena.

2. **The Three Problems of Physiology.**—*Nutrition* (Fig. 1). Look at that brood of little chickens in the court-yard. Not one of them weighs much above half a pound; yet in a few months they will be as big as the old ones, and will weigh several pounds. After that they will remain about the same size and weight all their life long.

Were I to ask how they are able to grow thus, where they find these pounds they thus add to their first weight, you would unhesitatingly answer that it is the result of the grain they eat, of the *nourishment* they consume. But do you think that in six months' time they have eaten only one or two pounds' weight of food? Ah! the farmer's wife would tell you that you were greatly mistaken if you fancied this, and would speak of bushels instead of pounds. It is then

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What is physiology?

but a *very insignificant part of their food* that remains in their bodies and is profitable to them. Moreover, even when they have reached their full growth, they continue to eat, *although their weight no longer increases.* What, then, becomes of the food they eat, and of what use can it be to them?

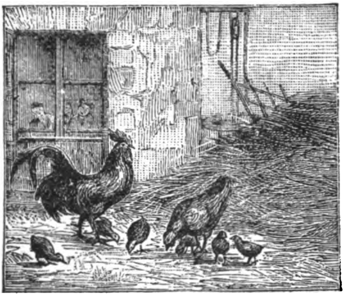

FIG. 1.—In six months the little chickens will be as big as the old ones: *nutrition.*

This is the first problem that Physiology presents to us: *What becomes of food, of what use is it, and why do we take it?* for we are absolutely obliged to eat, under penalty of death from hunger. This is the problem of NUTRITION.

3. Sensation. Motion.—Yet, notwithstanding the importance of the problem of nutrition, it is neither the most curious nor the most difficult of those presented to us by animal life.

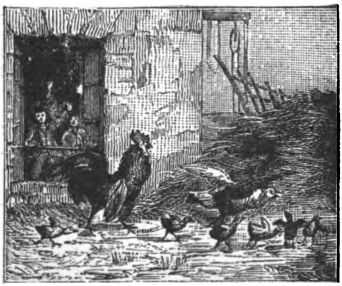

FIG. 2.—They are afraid: *sensation.*—See how they run: *movement.*

Open the window suddenly and halloo at the chickens. *See how they run away* (Fig. 2). They are frightened. Now let them get over their fright, and throw them some crumbs of bread. *There they come running to pick it up*, quite delighted, the mother hen and all. What does this signify?

This shows in the first place that they *heard* the noise you made, that they *saw* your gestures; in a word, they knew, they *felt*, that something or somebody was there. It also shows that they *understood* that the noise and gestures were

What is the first problem we meet with in physiology? What name is given to it?

threatening in the first experiment, and inviting in the second. In short, this implies that, having understood, they moved; *they gave orders to their feet and wings to move*, so as to enable them to avoid a danger that they believed to menace them, or to profit by an advantage they saw offered to them.

Here, then, are two other problems. First, *How are animals capable of feeling, understanding, willing?* This is the problem of SENSATION and of INTELLIGENCE. Then, *By what means are their orders obeyed?* How is it that the whole body, the feet and wings when there are any, obey the order, and execute the necessary movements? This is the problem of MOTION.

We have, then, before us three great problems. We will study them one after another. I will first speak to you about *motion*, because it will lead us to learn the history of the *bones* and the *skeleton*, which we must necessarily understand in order to be able to study the other two problems.

I.—MOTION.

4. The Three Factors of Motion.—Come here beside the table and lay your forearm A flat upon it (Fig. 3). Now fold your forearm A backwards towards your arm B (Fig. 4). Very well: this is a *movement*. Let us see what has taken place.

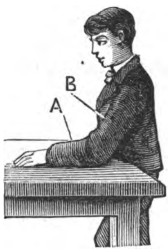

FIG. 3.—Put your forearm A flat on the table.

FIG. 4.—Fold the forearm A back upon the arm B.

You are all perfectly aware that there is a *bone* B (Fig. 5) in the arm and another *bone* C (in reality there are two) in the forearm.

These bones are in contact with each other at A, the elbow, and there work upon each other. The movement you made had the result of bringing near each other the

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What is the hard substance we feel in our forearm? What is the second problem in physiology? What is the third?

bone C and the bone B, just like the two arms of a compass.

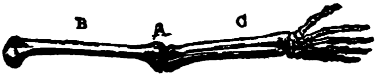

FIG. 5.—The bones C and B play on each other at the articulation A of the elbow.

These bones are hinged on each other at the elbow, a part arranged for that purpose, and which is called a *joint*, or, to use a better expression, an ARTICULATION.

These bones are harder than wood. Were they all alone

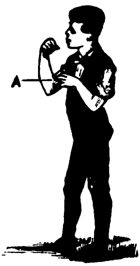

FIG. 6.—You feel something at A that is hard and bulky.—It is the flexor *muscle* of the forearm.

they would remain end on end, no more able to move than the arms of the compass. Something else is necessary to enable them to move, and this something is what is called a *muscle*.

Once more I ask you to bend your forearm back upon your arm. And whilst you do so, grasp with the other hand the thick part of your arm. During the movement you can feel at A something that grows harder and thicker under your grasp. This is the great motor muscle of the forearm, or, to use the physiological expression, the *flexor muscle* of the forearm, that is in action (Fig. 6).

There are, then, in this movement three parts to be considered: *bones*, *articulations*, and *muscles*.

1. The Bones, or the Skeleton.

We have learned in the Natural History that *skeleton* (Fig. 7) is the name given to the bony framework of the whole body, and that this skeleton is composed of three great and distinct parts: the *vertebral column* with the ribs B, the *skull* A, and the *bones* CC *of the limbs*.

5. Various Shapes of Bones.—These bones are extremely varied in shape. Look at these chicken-bones that I laid aside

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What name is given to the point at which bones play on one another, for example, the elbow? What name is given to that which causes the bones to move? How many organs, then, have we to consider in each movement? What is a skeleton? What are the three great parts that compose a skeleton?

at dinner yesterday (Fig. 8): some are long, A; others are flattened out, B; others are short and irregularly shaped, C. But, although so different in form, all are of similar chemical composition.

6. Composition of Bones.—See, I put one of these bones into strong vinegar (Fig. 9). Imme-

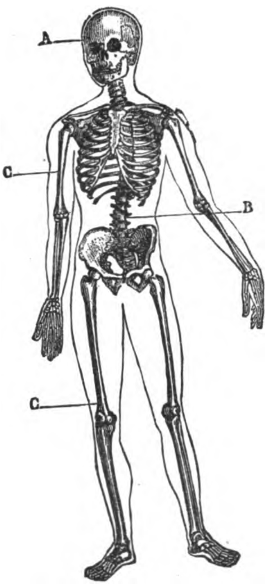

Fig. 7.—Human skeleton. A, skull; B, vertebral column; C, bones of limbs.

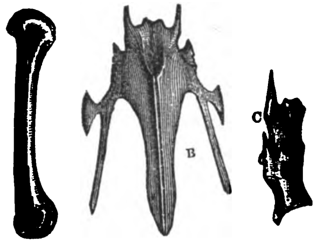

Fig. 8.—Chicken-bones.

Fig. 9.—Bones contain carbonate of lime, phosphate of lime, and organic matter. It is from bones that phosphorus is extracted.

diately tiny bubbles of gas escape from it: this gas is carbonic acid. For *carbonate of lime* is one of the constituents of bones. They also contain *phosphate of lime; indeed, it is, as I have already told you, from bones that phosphorus is extracted.*

See, here is a bone similar to the one we have just spoken

Have all the bones the same shape? Name the two salts of lime contained in the bones. What substance do we obtain from bones?

about, but which has remained steeped in vinegar for several days. The *carbonate of lime and phosphate of lime* have both been dissolved, and that which remains of the bone is quite flexible. If I put it in the fire it will entirely disappear. This is what is called the *organic* part of the bone.

It is the living part of bone.

Thus, in bone there are two parts intimately related to each other: ORGANIC matter and MINERAL matter.

This last has not always existed in the bone. *When very young, bone contains no mineral matter:* it is at first quite SOFT and FLEXIBLE; afterwards the earthy matter makes its appearance in certain parts. These soft, flexible young bones are called gristle or CARTILAGE.

7. Structure of Bones.—Let us cut this rabbit's bone across; it is the thigh-bone (Fig. 10). You can see that it

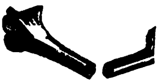

FIG. 10.—The bone is hollow and contains *bony marrow*, which has the property of making bone.

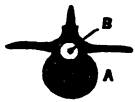

FIG. 11.—The vertebra of a rabbit, showing the spongy tissue A.

is *hollow*, and encloses a sort of canal. In this canal is to be found a pulpy substance called MARROW. It is from this marrow that the bony substance is formed, both originally and for purposes of repair when a bone has been broken, or *fractured*, as doctors say.

Here is a rabbit's vertebra (Fig. 11). I also cut it across. We do not find here a canal for marrow; but the bony marrow exists all the same in this sort of *internal net-work* A which has some resemblance to a sponge; hence the name of *spongy tissue* given to it.

8. Vertebral Column.—THE VERTEBRAL COLUMN AB

What remains when the carbonate and phosphate of lime are dissolved in vinegar? What name is given to this matter? What part of the bone is it? In that case, what is there in bones? What peculiarity do the bones of young animals present? What name is given to bones that are soft? Are bones solid or hollow? What is in the internal cavity of bones? What property does marrow possess? By what is the canal for marrow replaced in vertebræ?

(Fig. 12) is formed of a series of VERTEBRÆ, A, piled the one on the other. Each vertebra (Fig. 13) is composed of a solid mass, or *body*, A, and a bony *ring*, B, behind. Pray observe I say "behind" because I speak of our own vertebral column; were I alluding to a quadruped I should say "above."

All these rings placed one above another enclose what is called the *spinal canal.*

Several regions are observable in the vertebral column.

First the *neck*, or *cervical region*, C, composed of *seven vertebræ* that have nothing particular about them. Then the thoracic or dorsal *region* D, composed in mankind of twelve vertebræ. Each of these bears a special bone or RIB E directed forward in a curved manner, and united to the opposite rib by the *costal cartilage* F and a series of bones G that you can easily feel in front of the *chest*, and that is called the *sternum.* The thoracic vertebræ and the ribs, along with the costal cartilages and the sternum, form thus a sort of open cage, wider in its under parts than in its upper, commonly called the *chest*, and scientifically the THORAX (a Greek word that has the same meaning).

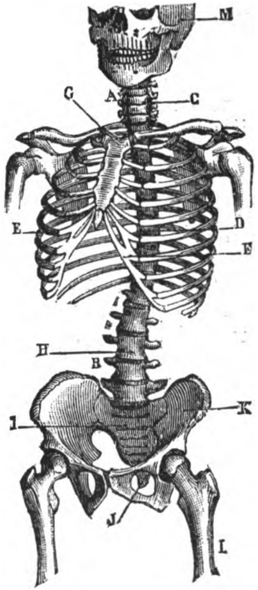

FIG. 12.—AB, vertebral column, containing the spinal canal behind.
E, ribs; F, costal cartilages; G, sternum; I, sacral region; J, caudal region.
K, bones of the pelvis (hip).
L, thigh-bone (femur).
C, cervical region.
D, thoracic region.
H, lumbar region.
I, sacral region.

Of what is the vertebral column formed? Of what is each vertebra composed? What do all these rings, placed one on another, form? What name is given to the region of the neck? Of how many vertebræ is it composed? What name is given to the region of the back? Of how many vertebræ is it composed? What important peculiarity do the vertebræ in the dorsal region present? In what manner is each rib united to that opposite? What do the dorsal vertebræ, the ribs, the costal cartilages, and the sternum form?

Below the dorsal region comes the *lumbar region* H, with ribless vertebræ like those of the neck C, then the *sacral region* I, in which five vertebræ are joined together so as to form only one bone, the SACRUM, with which the bones K of the lower limbs articulate.

FIG. 13.

Vertebra seen from the front. Vertebra seen from above.

A, *body* of the vertebra.
B, ring or arch forming with those of the other vertebræ the spinal *canal*, in which is found the *spinal cord*.

Lastly, there is the *caudal region* J, which in long-tailed animals has often a great number of vertebræ, but in mankind is reduced to two or three little bones called *coccyx*.

9. Skull.—At the upper end of the vertebral column is situated the SKULL (Fig. 14). It is a sort of bony box, the cavity of which opens into the spinal canal (see § 51).

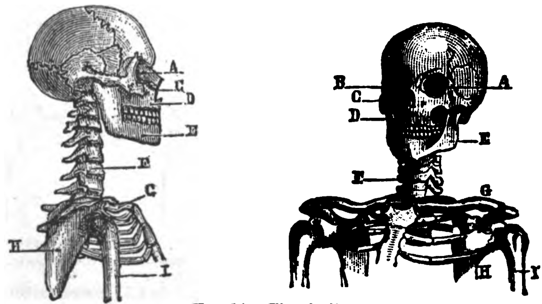

FIG. 14.—The skull.

A, B, orbits of the eyes.
C, nasal chambers.
D, upper jaw, fixed.
E, lower jaw, movable.
F, vertebræ of the neck.
G, clavicle (collar-bone).
H, scapula (shoulder-blade).
I, humerus (arm-bone).

The skull is composed of a goodly number of bones, whose names we will hereafter learn. In front are the cavities or ORBITS A, B, in which the eyes are set; C, the NASAL CHAM-

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What region comes after the dorsal region? What name is given to the five vertebræ joined together in the sacral region? What bones does the sacrum support? What name is given to the three little bones in the caudal region? What is placed at the upper end of the vertebral column?

BERS, and the two JAWS D, E, set with teeth, between which is the opening of the *mouth.*

The *upper jaw* D is stationary, being a part of the skull. On the contrary, the *under jaw* E is movable, articulating with the skull, as you all know.

10. Limb-Bones.—*The upper limbs* (Fig. 15) (*fore-limbs* in quadrupeds) are composed of several parts, as you know: the *arm* (from the shoulder to the elbow), *forearm*, *wrist*, *palm*, and *fingers*. The names given to the bones are—HUMERUS, for that of the arm D; RADIUS and ULNA, for the bones E, F, of the forearm; CARPUS, for the wrist-bones G; METACARPUS, for the bones H of the palm; PHALANGES, I, the finger-bones. In reality, the metacarpal bones (those of the palm) are simply the first phalanges, the only difference being that they are not free like the others; but in this bat's wing you can see they are quite similar to the others, so that each finger seems to have four phalanges, A, B, C, D (Fig. 16).

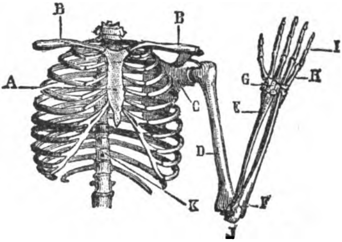

FIG. 15.—Upper limb (arm and forearm).

A, sternum (front of the chest).
B, clavicle.
C, scapula.
D, humerus (arm).
E, radius } forearm.
F, ulna }
G, carpus (wrist-bone).
H, metacarpus (palm).
I, phalanges (finger-bones).
J, elbow (extremity of the ulna).

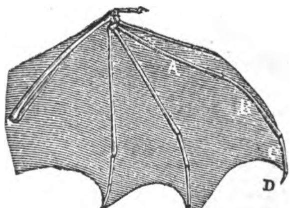

FIG. 16.—Extremity of a bat's wing, showing the four phalanges of the fingers, A, B, C, D.

One of the two bones of the forearm, the ulna F, is the direct continuation of the humerus D: its upper end, J, forms the *elbow*, hence it is sometimes called *cubitus*, a Latin word meaning *elbow*. It so fits

What are the cavities in front of the skull? Is the upper jaw fixed or movable? And the under jaw? What names are given to the different parts of the upper limbs? What name is given to the bone in the arm? To the two bones in the forearm? To the wrist-bones? To the bones in the palm of the hand? To the finger-bones?

the humerus D as to execute only movements like the hinge of a door. The other bone, E, *radius*, turns on the ulna in a very curious manner, carrying along with it the wrist and the whole of the hand. These movements of the radius render us most important services: in this respect no animal is so well endowed as man.

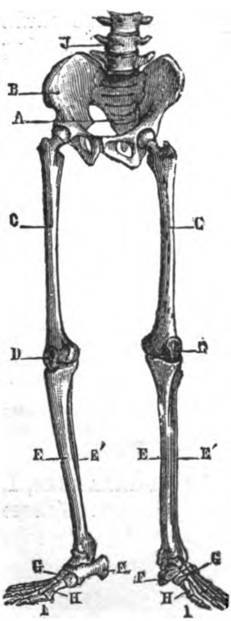

Fig. 17.—Lower limb (thigh, leg, and foot).

A, sacrum (inferior extremity of the vertebral column).
B, pelvis (hip).
C, femur (thigh).
D, patella (knee-cap).
E, tibia } (leg).
E′, fibula } (leg).
F, G, tarsus (instep).
H, metatarsus (sole).
I, phalanges (toes).
J, vertebræ (lumbar).

The arm is attached to the body by two bones: the SHOULDER-BLADE (see preceding page), a flat bone, with which the *humerus* D is articulated, and which is directed backward and lies upon the thorax, without being united with it anywhere; and the CLAVICLE B, or COLLAR-BONE, placed like a cross-bar passing between the shoulder-blade and the sternum A, where it is firmly fixed.

In the *lower limb* (Fig. 17) we distinguish the *thigh*, the *leg* (from the knee to the foot), the *instep*, the *sole*, the *toes*.

The names of the bones are—FEMUR C, the thigh-bone; TIBIA and FIBULA, the two bones E, E′ of the leg; TARSUS, the bones F, G of the instep; METATARSUS, the bones H of the sole; PHALANGES, the bones I of the toes. The *tibia* is the thick bone of the front of the leg, shin-bone as it is called: it supports the body, and extends from the *femur* C to the *tarsus* F; the *fibula* is a long slender bone: it has no special use.

What does the upper end of the humerus form? What peculiarity does the radius present? By what bones is the arm attached to the body? What are the parts of the lower limb? What name is given to the thigh-bone? To the two bones in the leg? To the bones in the instep? To the bones in the soles of the feet? To the bones in the toes? What is the tibia? The fibula?

The two femora C, that of the right thigh and that of the left, articulate upon a broad and solid bony girdle B, called the PELVIS, A (the haunch), which is joined at the back to the sacrum (the *under* end of the vertebral column). This forms a solid base upon which the body can rest.

So much for the bones. We will now pass on to the study of their articulations.

2. Articulations.

11. Articulations *are*, as I have already told you, *the parts* D (Fig. 18) *where any two or more bones, that are to play on one another, come in contact.*

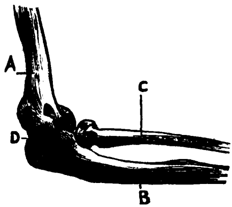

Fig. 18.—D, articulation. A, humerus; B, ulna; C, radius.

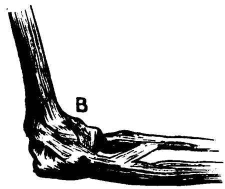

Fig. 19.—B, ligaments holding the bones in place.

In order to facilitate their movements, these parts of the bones are covered over with a sort of polished, shiny cap of gristle, constantly kept moist by some drops of liquid. And in order to assure sufficient firmness to the articulation, fibrous bands, or LIGAMENTS (Fig. 19), pass from one bone to another.

You can easily understand that articulations may be very differently shaped, according to their destined functions. But these are details into which we cannot enter at present.

12. Fracture of Bones.—It sometimes happens that a bone is broken by a blow or a fall; surgeons then say that the bone

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Upon what do the two femora articulate? To what bone is the basin or pelvis joined? Give the definition of an articulation. What facilitates the movements of the joints? How is the firmness of the articulation assured?

is *fractured*, and they bring together the two ends of the broken bone, and fasten them by strips of wood, called splints, and linen bandages, so that the limb cannot move. Then it is necessary to wait till the bone mends itself; for after some time there forms between the two ends of bone a substance which becomes also bone, and holds the two pieces firmly together. This substance is called *callus*.

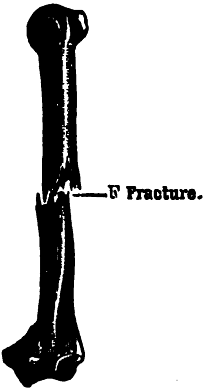

Fig. 20.—Broken bone.

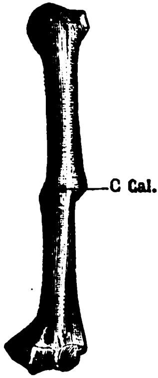

Fig. 21.—The two fragments are united by *callus*.

Distortion of the Spinal Column.—The chain of bones that forms the spinal column is very movable, and this it is that enables us to bend our bodies pretty much as we will; but this mobility also presents certain dangers, for if while young you acquire bad habits of position, if you sit in im-

Fig. 22.—What follows from leaning too much on one elbow: high-shoulder.

Fig. 23.—Skeleton of a high-shouldered child.

Fig. 24.—Stoop-shoulder.

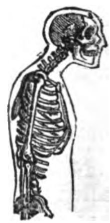

Fig. 25.—Vertebral column in stoop-shoulder.

What is a fracture? How do fractured bones become reunited? What frequently is the effect of improper positions while young?

proper attitudes, leaning on the desk or on one elbow,—all those things that you are continually forbidden to do,—you run the risk of making one shoulder higher than the other, or of twisting the spinal column so that it will not again become straight. Then the body is more or less deformed. Think of this, and remember that it is not for the pleasure of seeing you all straight in line at your desks that I continually admonish you.

13. Injuries to the Articulations.—When the articular ligaments are too strongly stretched, or even somewhat torn, as sometimes happens when one makes a false step or other movement, the joint is said to be sprained. If the ligaments have been badly torn, and the two bones are no longer held in place, there is a *dislocation*.

Sprains generally cure themselves with rest and time, but it is very different with dislocations; these must be attended to promptly, and it is necessary to pull the bones into place. A delay of a few days makes this very difficult, and after a few weeks it becomes impossible, and the person is often lame for life.

When a fractured bone is left to grow together crooked, or an articulation to become immovable, deformity is not the only danger: an improperly cared-for sprain or blow on a joint often endangers life itself. The articulation may become inflamed, water forms in the joint, the bones become thickened, and a terrible affection called *white swelling* results. In all such troubles a good surgeon should be called as soon as possible.

3. Muscles.

14. What physiologists call *muscle* is what is commonly called *flesh*, or, more vulgarly, *meat*. You can easily see that it consists of a mass of red threads or fibres, C (Fig. 26), placed alongside of one another, and fastened to a bone at each end.

Often the muscle is not itself fixed on the bone, but is at-

What is a sprain? A dislocation? By what name are muscles commonly known? Give a definition of a muscle.

tached to it by strong whitish cords A, A, called by anatomists TENDONS or SINEWS. The muscle in this case acts by the intermediary of the sinew, as you might draw anything with the help of a rope, and not directly with your hands.

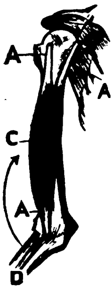

FIG. 26.—C, one of the muscles of the arm. A, A, tendons. When the muscle C contracts the forearm D is raised.

15. Muscular Contractility. — The filaments or fibres of muscles have a very peculiar property. When they are pricked, or cut, or burned, or struck, when they are excited by electricity, in a word, whenever and however they are irritated, they *shorten*, or, to use a more technical expression, they CONTRACT, as physiologists say. Evidently this brings their two ends nearer to each other, and along with them the bones to which they are fastened.

This is what happened to your forearm a little while ago.

In your arm there is a muscle that passes from the upper part, A, of the humerus to the beginning, B, of the *forearm*. When it shortens, since the humerus is solidly fixed to the shoulder, the result is that the forearm is lifted up in the direction of the arrow, carrying the hand along with it. Of course the muscle cannot become shorter without becoming thicker; and that is why you felt it become hard and bulky in your arm.

A very curious thing it is to study closely this *contraction* of the muscles. Luckily, the farmer's wife has brought for supper a rabbit that was killed but a few minutes ago. Let one of you fetch me the electric pile. I touch the two ends of the muscle A with the two poles (Fig. 27): see how it immediately swells out and *shortens;* and yet the rabbit is quite dead.

16. Number and Variety of Muscles.—All other muscles give a similar result, and you see I provoke all sorts of

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How are the muscles attached to the bone? What peculiarity do they present? What are the consequences of this contraction? Show the effect of muscular contraction in your forearm. How can a muscle be made to contract by artificial means?

movements by exciting successively the different muscles of the dead rabbit.

And these are not few in number. Some set the feet in motion, or bend or spread out the toes; others act on the position of the head, others on the vertebral column, others on the abdomen. In short, to give you some idea of their number, I may tell you that upwards of two hundred have

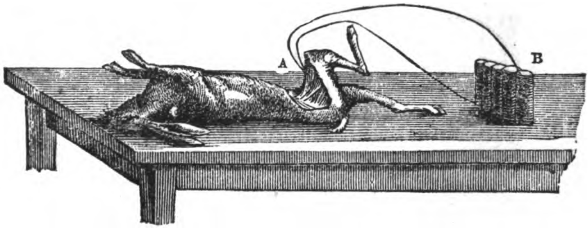

Fig. 27.—I touch the two ends of the muscle A with the two poles of the pile B: the muscle *contracts*.

been counted in a man's body, each having its own special part to play.

You must understand, however, that it is not my intention that we should study all these muscles; that is for doctors and surgeons to do, for they must needs be well versed in *anatomy*,—that is to say, the details of all the parts of the body.

17. Death-Stiffening.—See, the muscles of the rabbit hardly contract any longer: in a few minutes it will even be impossible to excite any one of them; they will be quite stiff. This is what is called the DEATH-STIFFENING. This inevitably happens in all dead animals. When it ceases, the muscle is ready to rot, or, properly speaking, to *putrefy:* we say *putrefaction sets in.*

Locomotion.

18. There are many kinds of movements that are executed with the aid of the *muscles:* for instance, we can at will bow

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What phenomenon may be observed in all dead animals? When the rigidity ceases, into what state will the muscles shortly enter?

down, lift up or turn about our head, carry our hands to our mouth, or put them behind our back, open or shut our jaws, our lips, our eyes, etc.

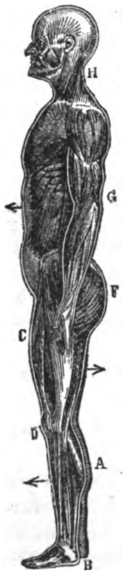

FIG. 28.—The upright position is not a state of repose, far from it: it can only be maintained by *contracting* certain muscles.
A, muscle of the calf which prevents the leg (from the knee to the foot) from falling in front.
C, muscle which prevents the thigh from bending backward.
F, muscles which prevent the body from falling forward.
G, muscles of the loins which sustain the vertebral column.
H, muscles of the neck which support the head.

But there are some movements of peculiar interest because they enable us to move from place to place, to walk, to run, etc. These are said to be movements of LOCOMOTION (from the Latin *locus*, place, and *movere*, to move). It is to such movements I now wish to direct your attention.

19. Standing.—In the first place, I must tell you about the muscular action required to STAND UPRIGHT.

I seem rather to astonish you.—"Why, yes, you speak about movement: when a person stands he makes no movement, for he does not stir from the spot."—What you say appears true enough certainly, and yet it is not so; for if the person makes no evident movements, at least he hinders certain movements being made. See, stand up before me. Do you think you could remain so for a long time?—"Oh, no! one is soon tired of standing motionless."—Why should one soon be tired?—"Because he must keep perfectly upright."—And how do you keep yourself quite upright? By stretching your legs, your back, and your body, is it not? What

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What name is given to the movements that enable us to walk? What name is given to the muscular actions that enable us to stand upright? How do you keep yourself upright?

would happen were you not to stretch yourself up?—"My legs would bend, and I should fall down."—Well, of course that would be the result, and certainly this downfall would be a movement, though an unpleasant one, which you would rather avoid. How do you avoid it? *By contracting certain muscles.* Follow attentively what I am going to tell you.

See here, your foot rests firmly on the ground. If you did not keep your muscles tight, your *leg*, from D to B, would bend forward. To keep it from doing so, the muscles A of the calf of the leg (Fig. 28), which reach from the tibia (shin-bone) to the heel, contract vigorously. Put your hand on them, and you can feel that they are hard. Thus you see the leg is fixed straight above the foot. Again, were you to let your muscles slacken, the *thigh* from D to C would bend backward. To keep you upright, a powerful muscle C, situated in front of the thigh, contracts and straightens it. This muscle presents a curious peculiarity. At its lower end it is terminated by a thick *sinew;* this is in itself not different from other muscles that we have already seen, but what is very remarkable is, that in the middle of the sinew there is a small bone called the patella, or KNEE-PAN, that presses upon the femur (thigh-bone), and tibia (shin-bone), when the muscle is in action, and so closes the front of the knee-joint: with your fingers you can easily force this patella to move.

So much for the leg and the thigh. But the *body* would also fall forward were it not kept up by the large muscles that are fastened behind to the pelvis (the haunches). Lastly, the *vertebral column* and the *head* are kept up and sustained in erect attitude by the contraction of the muscles of the loins G and the neck H.

So you see your body is by no means at rest when standing upright.

It is for this reason that the calves of the legs, the thighs, the loins, and the neck are soon pained under prolonged standing. Even when seated, neither your vertebral column nor

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Which muscles prevent the leg, from the knee to the foot, from bending forward? What muscle prevents the thigh from bending backward? What peculiarity does this muscle present? Which muscle prevents the body from falling forward? What are the muscles that sustain the vertebral column and the head? What conclusion do you arrive at in consequence? What are the results of standing a long time?

your head is at rest. And that is why backs were invented for chairs; for that reason also you let your bodies lie forward on your desks, although you are told that this is a very bad habit, and that you may become hump-backed if you do not take care.

20. Walking and Running.—From *standing* to *locomotion* the transition is easy. You that have remained on foot, lean forward; more so, and yet more so. Ah, you were just going to fall, so you put forward your left foot: in doing this you made a *step*. There, you are now in equilibrium on your two feet set apart. Lean forward once more; again you feel ready to fall, and this time it is the right foot you pass rapidly in front of the left. You have thus taken another step, you have WALKED. *Walking is then a series of partial falls in a forward direction: falls checked just in time.*

In walking, at least one foot is always on the ground, the body being supported alternately by the one and the other. In *running*, the feet are in such rapid motion that they are never both on the ground at the same time; and at regular intervals the body is altogether in the air, and not in contact with the soil at all. So *running is a series of leaps.*

There is great variety in the detail of locomotion of animals.

Quadrupeds *walk*, *trot*, *gallop*, etc.; aerial animals *fly;* aquatic animals *swim;* limbless animals *creep*. But however varied these movements may outwardly be, they are always *the result of muscles contracting and acting upon solid parts.* In the case of vertebrates, the solid parts are the bones; in the case of invertebrates, the muscles act upon the hardened skin, as with insects, for example: be this as it may, the *muscle* always plays the most important part in motion.

21. Voluntary and Involuntary Motion.—All the movements of which we have just been speaking are VOLUNTARY. You can lift your arm or keep it at rest, or open or close your mouth at will. *Yet there are movements that you can make*

What is walking? What is running? Name the different varieties of locomotion in animals. In a general manner how are these movements produced? By what are the bones ordinarily replaced among the invertebrates? Name some voluntary movements.

at will, but which your will cannot prevent. Thus, you can wink as often as you like; but I defy you to keep from winking were I to touch your eye, or even were I to make you believe I wished to touch it: you can also quicken your breathing, but you cannot avoid breathing. Put a bit of bread in your mouth and chew it; as long as it is in your mouth you can do what you will with it, but once it enters into your throat it is seized, carried off and swallowed without your having any more power over it. We have then before us a second category of movements that are to a certain extent both *voluntary* and *involuntary*.

There are also others, quite INVOLUNTARY, *which we can neither produce nor hinder, and of which we often have no knowledge.* For instance, unless we put our hand on our breast *we do not feel our heart beat; we have not the sensation* that our stomach and our intestines contract, and *we might vainly endeavor* to accelerate the beating of our heart or the contraction of our stomach.

These movements, over which we have no control, are the most important for the preservation of our existence. Were we able to arrest the beating of our heart or our respiratory movements, we should immediately perish: it is therefore better for us that we have no power over them.

FIG. 29.—The muscles that we bring into play become stronger: witness the arms of the blacksmith.

22. Gymnastic Exercises.—When a muscle is continually exercised it becomes THICKER, HARDER, and STRONGER. This is the reason that bakers and blacksmiths have such large arms, for they must work hard at kneading the dough or raising the heavy hammer with which they strike the anvil. The exercise strengthens the muscles of their arms; in the same manner much walking thickens the muscles in the calves of the legs.

Mention some movements that can be produced at will, but that cannot be prevented. Name some others that are quite involuntary.

You can thus see the usefulness of exercise, and why it is that after you have worked well in school it is good for you to walk, run, play ball, and row if this last is possible, for the exercise develops the muscles that have been idle in the school-room. Those who pass their lives in offices, with little or no moving about, as is often the case in cities, can never be very strong.

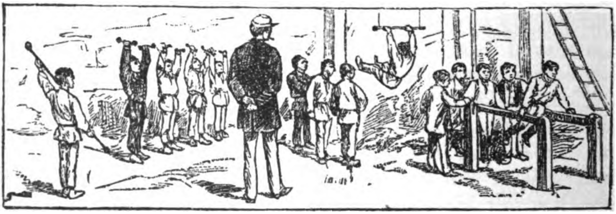

FIG. 30.—Systematic gymnastic exercises bring into play and develop all the muscles of the body.

But the best exercise for the muscles is gymnastics, which may be so arranged as to give all the muscles of the body their proper exercise. Then one becomes strong not only in the legs or arms, but in the whole body, and one is fitted for work of any kind.

Diseases of the Muscles.—Sometimes the muscles contract in an exaggerated manner so as to cause great pain. This contraction is called *cramp*. The application of cold or heat, friction, and the forced stretching of the limb generally cause the cramp to pass away quickly.

It is partly in the muscles that are situated the *rheumatisms* which are brought on by exposure in cold damp places, and which may generally be prevented by carefully avoiding such exposure.

How may the muscles be developed? What is cramp?

SUMMARY.—MOTION.

1. The three problems of physiology are NUTRITION, SENSATION, and MOTION.

2. Motion (p. 9).—In every movement there are to be considered: the *bones*, the *joints*, and the *muscles*.

3. Bones (p. 10).—The skeleton is composed of three distinct parts: the *spinal column and ribs, the skull,* and the *bones of the limbs.*

4. The bones are composed of an organic or animal substance called *cartilage,* and a stony mineral matter formed of *carbonate of lime* and *phosphate of lime.*

5. The *marrow,* which has the property of making bone, is found in the interior of the bone itself.

6. The Spinal Column (p. 13).—The spinal column is composed of *vertebræ,* which vertebræ are themselves formed of a solid *body* and a *ring* or arch.

7. The superposed rings of all the vertebræ form a sort of tube, called the *spinal canal,* which communicates with the cavity of the skull.

8. The dorsal or thoracic vertebræ bear *ribs,* united in front by the *costal cartilages* and the *sternum.* The kind of cage thus formed is the *thorax.*

9. At the lower part of the spinal column, five vertebræ, closely united, form one single bone, the *sacrum,* which is attached to the bone of the *pelvis* (haunch).

10. The Skull (p. 14).—The SKULL is placed at the upper extremity of the spinal column.

11. In the skull you can observe the *orbits* for the two eyes, the cavities of the *nasal chambers,* and, underneath, the two *jaws* bearing teeth.

12. The upper jaw, intimately united with the skull, is *fixed;* the under jaw moves up and down.

13. Bones of the Limbs (p. 15).—The bones of the upper limbs are: the *humerus,* which passes from the shoulder to the elbow; the *radius* and the *ulna,* from the elbow to the wrist; the *carpus,* which comprises the wrist-bones; the *metacarpus,* which comprises those of the palm of the hand; and the *phalanges,* or bones of the fingers.

14. The elbow is formed by the extremity of the ulna.

15. The humerus (arm-bone) articulates upon the scapula, or shoulder-blade, which is placed behind *upon* the thorax, but without being attached to the spinal column.

The scapula is supported by the *clavicle* (collar-bone), which extends from it to the *sternum* (breast-bone), to which it is solidly fixed.

16. The bones of the lower members are: the *femur,* which extends from the haunch to the knee; the *tibia* and *fibula,* which extend from the knee to the ankle; the *tarsus,* which comprises the ankle-bones; the *metatarsus,* which comprises the bones of the sole of the foot; and the *phalanges,* or bones of the toes.

17. Besides all these there is still another bone at the knee, called *patella.*

18. The two femora articulate with the *pelvis* (haunch-bone), which extends to, and joins, the *sacrum* (lower extremity of the spinal column).

19. Joints (p. 17).—JOINTS, or ARTICULATIONS, are those points at which two bones that play on each other come in contact.

20. To assure the solidity of the joints, there are bands or *ligaments* which go from one bone to another.

21. When a bone has been fractured there forms between the broken ends a substance called *callus* that firmly reunites the two portions.

22. A *sprain* is occasioned by the distending or rending of these ligaments; when any two bones are forcibly disconnected a dislocation is the result.

23. In order that the spinal column may not grow distorted, improper habits of position must be avoided while we are young.

24. Muscles (p. 19).—MUSCLES, commonly called *flesh* or *meat*, are masses of red filaments or fibres fixed to the extremities of the bones, and having the property of *contracting* or shrinking.

Instead of being fixed directly on the bones, they are attached by means of *tendons* or sinews, a sort of cord, white and firm.

25. It is our muscles that permit us to move our arms, legs, head, jaws, lips, cheeks, eyes, etc.

26. When we *stand* upright, it is the *contraction* of muscles that prevents the body from bending. To stand, then, is not to rest.

27. To lift your arms, to open your mouth, etc., are *voluntary* movements; but there are movements which are to a certain extent both *voluntary* and *involuntary*, such as winking, for example; others, again, are always *involuntary*, such as the beating of the heart, or the contracting of the stomach.

28. The proper development of the muscles requires regular and systematic exercise.

[Simple *Subjects for composition* are to be found at page 68.]

II.—NUTRITION.

23. How, and why, do we eat? We are all aware that we take food, that we *digest* it, that we *absorb* a part, and that we eliminate the rest. But how does all this work go on, and what is the use of it?

1. Digestion.

24. We procure food, we put it in our mouth; when this food is of little bulk, or when it is liquid, we swallow it immediately; when it is too big for this, we chew or masticate it, in order to break it up.

25. Teeth.—The process of *mastication* is accomplished with the help of the TEETH, that cut and masticate, and the TONGUE, a muscular organ, very active and easily moved, that

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How is mastication performed?

constantly brings the food under the teeth, and rolls it into a sort of ball when ready to be swallowed.

There is great variety in the shape of *teeth* (Fig. 31): in front they are sharp, *incisor* teeth A; on the sides, pointed, *canine* teeth B; behind, grinders, *molar* teeth C. I have, or rather I ought to have, in my mouth in each jaw, 4 incisors, 2 canines, 10 molars, altogether 32 teeth. You children when younger than seven years had only 20 in all, having but 4 molars in each

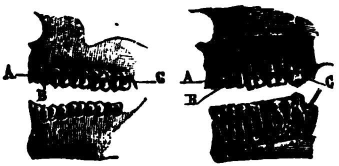

FIG. 31.—Human jaw, showing the teeth covered and uncovered by the gums.
A, incisors; B, canines; C, molars.

FIG. 32.—A cat's jaw.

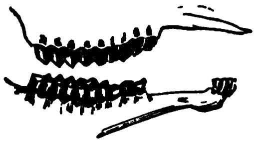

FIG. 33.—A sheep's jaw.

FIG. 34.—A rabbit's jaw.

jaw. You afterwards lost these, and your *second dentition* began.

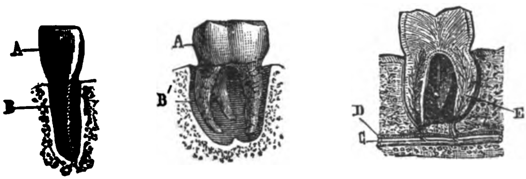

FIG. 35.—Teeth of man.

A, crown of the tooth covered with ivory.
B, root or fang of the tooth, implanted in the socket of the jaw.
C, veins } blood-vessels.
D, arteries }
E, clusters of nerves.

What are the different kinds of teeth? How many incisors has an adult man in each jaw? How many canine? How many molars? How many teeth have we up to the age of seven? Whence comes this difference?

The number and shape of teeth vary greatly in the different groups of animals. Those of the cat (Fig. 32) differ from those of the sheep (Fig. 33) and those of the rabbit (Fig. 34). But they all have essentially the same composition. They are all composed of ivory, and planted by one or several *roots*, B, B′ (Fig. 35), into pits or *alveoli* of the jaw. The part A that protrudes from the jaw-bone is covered over with *enamel*, a transparent substance harder than the ivory. Inside the tooth is a cavity into which run tiny *blood-vessels* and *nerves*.

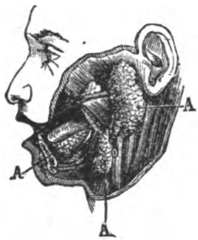

FIG. 36.—A, salivary glands.

When it happens that the enamel is destroyed, the ivory decays and spoils very easily, a hole is formed, and the tooth decays. If the hole reaches the cavity in which the nerves are lodged, it causes acute pain, as almost everybody unfortunately knows from experience.

26. Saliva.—The mastication of the food is facilitated by an outflow of *saliva*, a fluid formed in the SALIVARY GLANDS A (Fig. 36).

The name *gland* is given in physiology to organs that *secrete*,—that is to say, that make and give out particular liquids or products: thus, tears are formed in the *lachrymal glands*, sweat in the *sudoriparous glands*. The saliva runs into the mouth by several small openings, some of which are under the tongue, near its root, and are very easily seen.

27. Deglutition.—When the food has been properly masticated and mixed with saliva, the tongue guides it to the opening of the throat, where by a muscular contraction it is seized and swallowed. This operation is called *deglutition*.

28. Alimentary Canal.—The food then descends a sort of tube A (Fig. 37), called ŒSOPHAGUS, situated in front of the

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Of what material are teeth formed? How are they placed? With what material is the exposed part of the teeth covered? What is found in the cavity of the tooth? When is there a painful sensation? By what liquid is mastication facilitated? To what organs is the name gland given in physiology? Name some of the glands. How does the saliva enter the mouth? What is deglutition? What becomes of the food as soon as swallowed?

vertebral column; therein it traverses the whole neck and breast and arrives at the STOMACH, C. This tube is of course very long in long-necked animals, and it is quite easy to see the food passing down in the neck of a horse or a goose.

The stomach is a kind of pouch (Fig. 38), capable, in man, of holding between two and three pints. From it the food passes into the SMALL INTESTINE, another tube, about the thickness of one's thumb, and coiled on itself a great number of times. This leads into the LARGE INTESTINE, F, which carries off and expels the useless residue.

These intestinal canals are surrounded with muscular fibres, which by their contractions force the food from one end of the *alimentary canal* to the other,—that is, from the mouth to the large intestine.

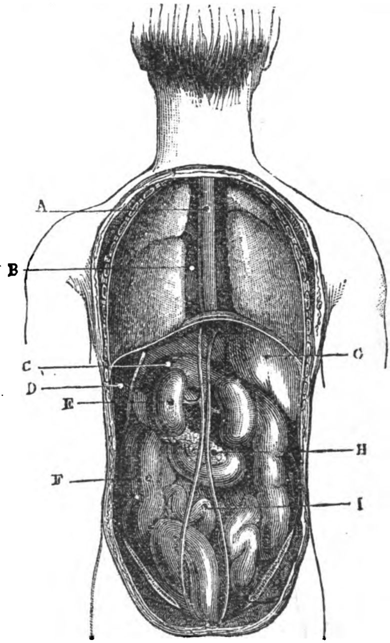

FIG. 37.—The organs of the chest and abdomen, separated by the diaphragm, seen from the back.

A, tube through which the food passes (œsophagus).
B, heart.
C, stomach.
D, spleen.
E, kidneys.
F, large intestine.
G, liver.
H, pancreas.
I, small intestine.

29. Digestive Juices.—But this is not what is most curious or most important in the digestive operation.

What may be observed in the alimentation of animals with long necks? About what is the capacity of a man's stomach? Where does the food go on leaving the stomach? Is the digestive canal composed of inert tubes?

Not only does the food make its way through the alimentary canal, but the useful parts are dissolved and transformed into new substances in this canal by the action of liquids or juices that are furnished by various glands as it passes along.

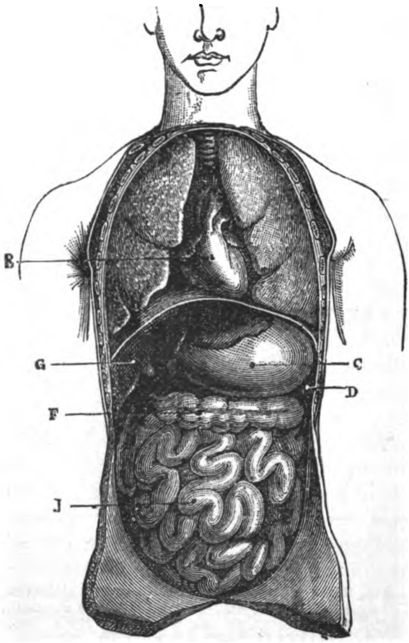

FIG. 38.—The organs of the chest and abdomen, separated by the diaphragm, seen from the front.

B, heart.	F, large intestine.
C, stomach.	G, liver.
D, spleen.	I, small intestine.

The first of these juices, and a very important one, is the *saliva*. If any of you has ever chewed a bit of bread for a good while, you may have observed that after some time the bread acquired a sweet taste.

And this is not astonishing, for saliva has the effect of *transforming bread into* SUGAR, or, to speak with more precision, saliva converts *flour or starch into sugar;* it is of no consequence whether this starch or flour be made from wheat or potatoes or peas, etc.

The coat of the stomach is covered with minute glands, from which a considerable quantity of juice called GASTRIC JUICE (from *gaster*, stomach) oozes out, drop by drop. *Gas-*

Does the food only pass through the digestive tube? Name one of the digestive juices. What is the effect of saliva? Name the juice secreted by the stomach. What is the effect of the gastric juice?

tric juice dissolves meat, white of egg, and in general all animal matter except fat.

The walls of the small intestine are furnished all over with small glands from which oozes a juice capable both of transforming into sugar all floury or starchy matter, and of dissolving all the meats that have escaped the action of the saliva and the gastric juice. Another gland, almost as big as my fist, known under the name of the PANCREAS, furnishes a juice which also acts upon meat, and upon floury and fatty matter.

There is also a large gland called the LIVER, G, lodged at the right side of the abdomen near the stomach. This secretes and pours into the small intestine the greenish-yellow bile: at the same time the gland effects important changes in the blood itself.

30. The Purpose of Digestion.—In short, you see that the *purpose of digestion is to* DISSOLVE *the food*, and so change it as to render it fit for use in the body.

2. Absorption.

31. Blood the Dispenser of Food.—But why all these processes? It is because *our food, in order to be able to feed and nourish us, must* PASS THROUGH THE COATS *of the intestine and enter the blood.* Of course if the food remained in a solid state this would be impossible.

If the food simply passed through the alimentary canal, it would be of no use to the body: one might almost as well have it in the hollow of the hand. *For the skin that covers over all our body enters from the lips and lines the whole alimentary canal:* Only from the lips inward the skin loses the appearance it has outside the body and becomes more tender and pulpy: in this state it is called a MUCOUS membrane.

The dissolved food must PASS INTO THE BLOOD, and be

What is the office of the glands that are found all along the small intestine? Among these glands, name one that is nearly as large as the fist. What is the function of the *liver?* What is the purpose of digestion? Why all these processes? Does the food produce any useful effect as long as it remains in the digestive tube? What name is given to the skin that lines the interior of the mouth? In what condition does the food serve to nourish us?

carried by it to all the parts of the body. For, as you well know, there is blood everywhere in your body: you may prick yourselves no matter where, with the finest of needles, a drop of blood will always be forthcoming.

32. Hygiene of Digestion.—The science of the conditions under which the body is kept in good health is called *hygiene*. When a tooth is put in vinegar it dissolves, just as we have seen is the case with bones. Now, there are formed in the mouth, especially when one is not well, *acids* that gradually dissolve the teeth. These then become decayed, or *caried*, as it is called, and great pain frequently follows: it is then necessary to go to a dentist. By brushing the teeth at least once a day, and carefully rinsing the mouth after each meal and before retiring at night, one may avoid many a toothache.

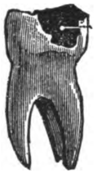

FIG. 39.—Carious tooth.

It is easier to prevent sickness by attention to hygiene than to cure it by medicine.

We may escape from very many sicknesses by regulating our meals, eating only those substances which are wholesome, and never eating too much. Eating too much brings on indigestion, with its disgusting accompaniments. Eating unripe fruit often causes colic, as those severe pains in the intestines are called with which you are probably acquainted. But the continual overloading of the stomach or eating of unwholesome substances does more than produce temporary inconvenience: it deranges the stomach and intestines, and brings on dyspepsia. Then good-by to tranquillity and good humor! He who has dyspepsia renders those around him as unhappy as himself.

You know that certain foods are furnished by animals, such as meats, eggs, milk and its products; these are called *nitrogenous* or animal foods, and are especially adapted to building up the tissues while we are growing or recovering

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What causes decay of the teeth? How may this be avoided? What is hygiene? What is meant by nitrogenous food?

from sickness. Most vegetable foods are *farinaceous:* such are bread and potatoes. Some vegetables, such as beans and peas, are nitrogenous, and fat, although derived from animals, is not nitrogenous. Farinaceous and fatty foods are adapted to the production of animal heat.

The food, especially meat, should be well cooked; it is then more digestible, and the heat of cooking destroys certain little living beings that sometimes exist in the meat, and that might give us severe diseases. It is because of the presence of these little beings that it is imprudent to drink impure water, especially in summer, without previously boiling it.

Typhoid Fever.—This leads me to speak of the danger of drinking water from wells or springs that are not far removed from privy-wells. All the liquids from such privies pass through the soil and poison the water in neighboring wells, and those who drink the water of the wells run the risk of typhoid fever. People are afraid of cholera, but the victims of typhoid fever are much more numerous.

Poisoning.—The stomach is not at all intelligent, and it absorbs all that goes into it,—the bad as well as the good. Food, useful medicine, and deadly poisons such as arsenic are absorbed without distinction.

When by accident a poison has been swallowed, the person should be made to *vomit* as soon as possible while waiting for the doctor, for it may be that all the poison has not been absorbed, and that there is still some of it in the stomach. The most simple way to bring on vomiting is to make the person drink a great deal of *warm water*, and to tickle the back of the throat with the finger or with the barb of a long feather.

There are no ANTIDOTES capable of counteracting all kinds of poisons, but there are some things that are useful in a great many cases, and that can always be given without danger. Among these are *milk* and the *white of egg*.

Medicines.—Those medicines that bring on vomiting are called *emetics;* those that increase the quantity of liquid secre-

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What is meant by farinaceous food? What is the danger of drinking impure water? How may vomiting be brought about? What is an emetic? A purgative?

tion in the intestines are called *purgatives*. Then there are others that are useful to cure diarrhœa. *Stimulants* increase the activity of the organs, and *narcotics* diminish this activity especially in the case of the nervous system, which we will study presently. When the organs are excited to increased action there is, of course, an increased wear on them, and the stimulation is followed by depression; continued stimulation consequently results in a diminished vigor, an enfeeblement, of the body. We can thus understand how the continued use of alcohol, which at first exerts a stimulating influence on the digestive organs, impairs the health of the alimentary system, preventing the digestion and assimilation of the food, and so interfering with the health of the whole body. Tea and coffee, also, are stimulants, and their too abundant use is frequently followed by derangements of digestion. Narcotics, such as opium (see § 63) and chloral, which are valuable medicines, and tobacco, while their immediate action is on the nerves, exert also a powerful influence on the digestive organs, interfering with all the processes of digestion.

When any medicine is necessary you should always go to the doctor, and pay no attention to the advice of those who pretend to know everything, but who really know no more than yourselves.

3. Blood and Circulation.

33. Blood.—Were I to ask, What is blood? you would all answer, It is a red liquid. And indeed it looks so. But, in reality, *blood is a yellowish liquid in which float a countless number of tiny red bodies* called *corpuscles*. In a cubic line there are about fifty millions of these little bodies (Fig. 40). Small though they are, they are so very numerous that it has been computed that were all the corpuscles contained in the blood of one man (about a gallon and a quarter) to be laid close in a single row end to end, they would form a chain long enough to go four times round the globe.

What is a stimulant? Why does the continued use of stimulants impair the health? What is blood?

34. Coagulation of Blood.—When blood is drawn from a blood-vessel and left in contact with the air, it coagulates; that is to say, it curdles into a jelly-like mass.

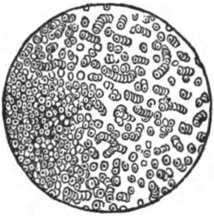

FIG. 40.—A, drop of blood, and its corpuscles, as seen with a microscope.

FIG. 41.—Small branches of a blood-vessel seen under a microscope. A, artery; B, vein; C, capillary vessels.

After a short time the more solid part thickens and shrivels up until it becomes a sort of dark-red clot, which floats in a yellowish liquid called *serum*.

This curious property of blood is of very great importance indeed: if the blood did not coagulate, the least cut or wound would bleed until complete exhaustion took place, whereas coagulation stops up the opening of the vessel, hinders the outflow, and allows the blood to go again on its regular course.

35. Circulation of the Blood.—Blood is contained in fine tubes or vessels that form a complicated net-work all through the body. In the chest, a little to the left, is the *heart*, B (Fig. 37), a sort of pouch, or rather a *hollow muscle*, that contracts with regularity, expelling the blood it contains.

The blood is brought to it by *veins*, and is carried out by *arteries*. The arteries branch off into smaller and smaller branches as they approach their destination (Fig. 41), and they terminate in very fine tubes called CAPILLARY VESSELS, thus named from the Latin word *capillus*, hair, although they are much finer than the finest hair. *These capillary vessels put the arteries in communication with the veins* (Fig. 42),

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What is the function of the heart? How is the blood taken to the heart? By what is it carried out of the heart? How do the veins and arteries terminate? What have the capillary vessels to do?

thus permitting what is called the CIRCULATION OF THE BLOOD. The veins, unlike the arteries, carry the blood back to the heart, and unite to form larger and larger trunks as they approach that organ. The blood flows with great rapidity from the heart through the arteries into the capillaries, thence into the smaller veins, then into the larger veins, which bring it back to the heart: all this course is gone through in half a minute.

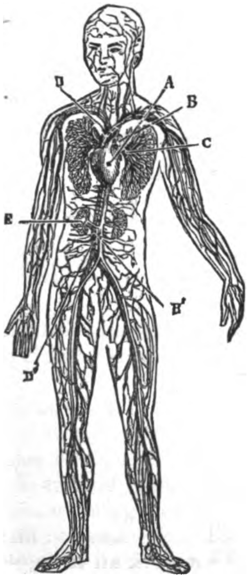

Fig. 42.—Circulation of blood.
A, heart.
B', trunk of the aorta.
B, origin of the aorta.
C, pulmonary artery.
D, posterior vena cava.
D', anterior vena cava.
E, veins and arteries of the kidneys.

The walls of VEINS are thin and flabby, so that when cut open they have a tendency to fall together, thus causing the opening to close: therefore, unless the wounds have opened the large veins of the thigh, or those of the armpit or the neck, but little danger is incurred.

On the contrary, ARTERIES are *rigid and tube-like*, and when one is accidentally cut, the blood bursts forth with such force that it sometimes springs three yards off, causing *hemorrhages* (from the Greek *haima*, blood, and *rhago*, to burst), which would soon prove fatal if the open artery were not bound up in time.

This property of arteries allows the blood under the impulsion of the heart (generally about once every second) to produce the *shocks* one can easily feel when the arteries are near the skin, as at the temples and the wrists: this is what doctors call the *pulse.*

What course does the blood take in going through the body? How long a time does it take? What is the nature of the coats of the veins? What is the nature of the coats of the arteries? What results from the rigidity of the arteries? What name is given to these shocks?

Of all that I have been telling you about the blood, what I most desire you to keep in mind is this: *there is a* CIRCULATION *caused by regular contractions of the* HEART, and resulting in the forcing of the blood from the heart along the *arteries* to the *capillaries*, and from these through the veins back again to the heart.

This is all we have to say on this subject at present.

4. Oxygenation.

36. I have already told you that, after having been reduced to a liquid state, the nutritive matter passes into the blood by a very curious mechanism, and that the blood then carries it off and *distributes the needful share to every part of the whole body; what remains* after this distribution is destroyed, or rather consumed, *burned up in the blood itself.*

This seems to astonish you. I think I can hear you say, it is really not worth while putting food in the blood merely that it may be destroyed! Besides, how could it be consumed, or burned? there is no fire in the interior of one's body.

Ah! *but there is fire in the body;* not a big raging fire, certainly, but a gentle fire, producing neither flames nor smoke. And the proof of this is, that *we have* (*when I say we, I include with us mammalia and birds*), as I have already said and shown you, *an internal heat* of 98 degrees Fahrenheit, a temperature much higher than that of the surrounding air. In the depth of winter, or in the icy regions of the North, when the outer air is 50 degrees below the freezing-point, when the very mercury freezes in the thermometer, *man still retains his* USUAL TEMPERATURE. You see, then, there must be some *internal fire* that keeps up this heat.

But, you ask me, what can produce this fire? What produces it in the stove?—"The coals we put in it."—Of course; but is it the coals alone? Ah! this puzzles you. What do you say?—"Why, air is necessary: if you close the

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What must be remembered about the circulation of the blood? Where do nutritive matters pass when liquid? What does the blood do with one part of this? What becomes of the other part? What proves that an internal fire is kept up in the body?

little opening under the fireplace, the fire will soon die out."—Quite right. What, then, makes the coal burn? Remember your lessons on chemistry.—"*It is the oxygen of the air.*"—Very well answered. And what is then produced, that escapes by the chimney along with the smoke?—"*Carbonic acid gas*, and sometimes *carbonic oxide.*"—Exactly so. Well, this is just what goes on in our bodies.

The aliments are burned by the OXYGEN *of air;* CARBONIC ACID *is also produced*, but never carbonic oxide. Let us look more closely into this; for really the thing is important enough to claim all our attention.

5. Breathing.

37. In the first place, how does the air enter the body?—"By the mouth."—What do you say?—"By the nose."—You are both right, as regards mankind and some other animals.

The real respiratory passage is the *nose:* the horse, for instance, breathes only by the nose, never by the mouth.

And where does the air thus introduced by the nose or the mouth pass?—"Into the chest."—That is true, but you would better say into the LUNGS.

38. Lungs.—You all know what LUNGS are like; they are what butchers call *lights.* They are often sold as food for pussy, who is said to be extremely fond of the dainty. I am very sure were these good people to ask pussy's opinion she would much prefer meat, for the lights are a spongy morsel, hard to chew, and containing, after all, little besides air.

See, as we have still our dead rabbit, we will just look how the lungs are arranged. The housewife may not be very well pleased, but science is well worth some sacrifice.

With a pair of large scissors you see I cut away part of the right and left ribs, and thereby the cavity of the chest is laid open. You can see the heart A (Fig. 43), and on each side the lungs B and C, soft and flabby.

What causes the coal to burn in a stove? What is then produced? Apply these phenomena of combustion to our bodies. Which is the real respiratory passage? Where does the air go that we breathe? What is the vulgar name that is given to lungs?

See here, alongside of the neck this tube D is strengthened from place to place by gristly rings. It begins at the back part of the throat, and communicates with the lungs: it is by this conduit that air reaches the lungs; its name is WINDPIPE. I make therein a little slit, and blow into it through a straw.

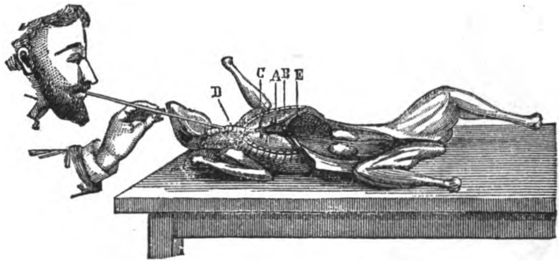

FIG. 43.—I blow into the windpipe D, and immediately the lungs, B, C, swell out, being filled with air.
A, heart; B, C, lungs; D, windpipe; E, diaphragm.

See how the lungs swell out with the air, which makes them look almost transparent. Whenever I leave off blowing they collapse, and expel nearly all the air they contained.

You see, then, lungs are *hollow* organs, whose structure is extremely complicated. I shall cut off a piece presently, and you will see that it very much resembles a sponge, full of air, as I told you a little while ago. The fact is, that it is formed by a multitude of small tubes called *bronchia*, closed at their inner ends, and so intricately mingled and knit together that it is almost impossible to trace them out.

39. The Larynx.—Such, then, are the organs into which the air penetrates. Before proceeding to examine how the air enters, I should like to tell you something about the LARYNX and the voice. The larynx, which we can easily feel with our thumb and finger, in front of the neck A (Fig. 44), is formed by an enlargement of the windpipe, whose

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What name is given to the tube that leads from the bottom of the throat to the lungs? Are the lungs solid or hollow organs? To what may they be compared? What name is given to the tubes that form the lungs? In what is the voice produced? Where is the larynx situated?

two upper rings have a greater development than the others and are shaped differently from them.

Inside there are two tightened folds A, B (Fig. 45), called *vocal ligaments* or *vocal cords*, that vibrate and become sonorous when forcibly struck by air, thereby producing the sounds of the voice. These sounds are subsequently modified by their passage through the throat, and by the action of the tongue, cheeks, and lips, and when thus articulated, as is said, they constitute speech.

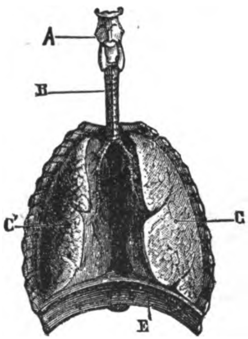

FIG. 44.—Our respiratory apparatus.
A, larynx (apparatus of the voice).
B, windpipe (through which the air passes).
C, C′, lungs, hollow pouches, that receive the air.
E, diaphragm (a thin and flat muscle that separates the chest from the abdomen).

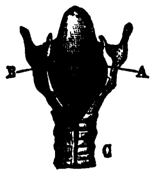

FIG. 45.—Slit up lengthwise in order to show the vocal cords A and B.
C, windpipe.

40. Respiratory Movements.—Let us now return to the entrance of air into the lungs. How does it penetrate? A little while ago, I blew air through a straw into the rabbit's windpipe. But very evidently nobody thus acts upon you.

Examine yourselves, each and all of you (Fig. 46), by putting one hand on your breast, and the other on your *abdomen.* You thereby verify what in fact you already knew, that, regularly, about fifteen times every minute, you take breath, and in so doing you make *respiratory movements.* And you are also aware that these are double movements; there being first INSPIRATION, afterwards EXPIRATION.

By what is the larynx formed? By what are the sounds of the voice produced? By the action of what organs are these sounds articulated? What are the two movements of respiration?

During *inspiration*, you feel your ribs raised and your chest widened out, while the abdomen swells as the *air enters* by the nostrils and passes into the lungs. During *expiration* the contrary takes place, the ribs sink down, the abdomen flattens, the cavity of the chest becomes smaller, and the *air is expelled*, as if from a pair of bellows.

FIG. 46.— Respiratory movements. At first there is *inspiration* (the ribs are raised), then *expiration* (the ribs are depressed).

As if from a pair of bellows! This is quite true. Air is drawn into the chest just as into a bellows, it is expelled also as from a bellows. See, here is a pair of bellows (Fig. 47): I close up with a cork the hole B which generally gives entrance to air; then I work the bellows as usual, and the air comes in and goes out by the pipe A, *just as it goes in and comes out of our lungs by our windpipe.*

Only in our body, instead of boards, there are ribs joined together by muscles covered over by skin, thus forming a sort of cage called the thorax. Do you see in our rabbit what closes the cage below? (Fig. 43).

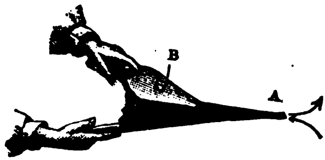

FIG. 47.—The air comes in and goes out by the tube A, exactly as it enters the chest and leaves by the windpipe.

It is a thin flat muscle stretched across between the thorax and the abdomen, and so separating the lungs and heart from the stomach, intestines, pancreas, liver, etc.

This muscle is called the DIAPHRAGM. When at rest, it forms a sort of arch (Figs. 38 and 43). When it contracts the arch flattens down; of course it thus gives greater ca-

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What is the action of the ribs during inspiration? How is the abdomen influenced? What does the air do? What happens during expiration? What becomes of the air? Explain the respiratory movements as compared with the action of a pair of bellows. By what is the floor of the thorax closed? What is contained in the chest? What is there in the abdomen? What is the muscle called that separates the thorax from the abdomen?

pacity to the cavity of the chest; and this causes a swelling out of the abdomen, for the diaphragm in descending presses upon the intestine; at the same time the air enters into the lungs by the windpipe (Fig. 48), just as it enters into the bellows, and other muscles raise the ribs, enlarging the chest still more. The sum of all these movements is *inspiration.*

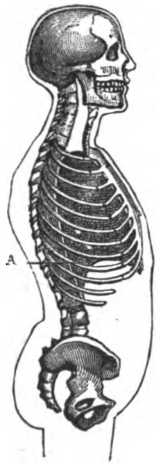

FIG. 48. — A, inspiration. The ribs A rise.

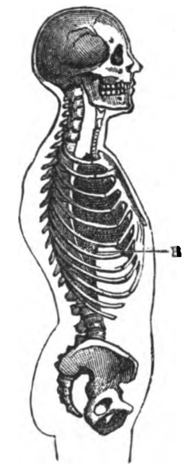

FIG. 49.—A, expiration. The ribs B fall.

Expiration is simpler still (Fig. 49). The diaphragm and the muscles that lift up the ribs cease to contract; the lungs, being very elastic, empty themselves and collapse, as I showed you in those of the rabbit, drawing down with them the ribs, and pulling up the diaphragm, which reassumes its arched position. The air naturally is expelled, at least the greater part of it, the cavity of the thorax is diminished, and the abdomen becomes flat.

You see the *mechanism of respiration* is not very difficult to understand. But yet it is not altogether so simple as I make it appear to you.

41. Production of Heat.—I have thus shown you how the air, and consequently oxygen, manages to enter into our bodies. But I see you have something to say.

"You said a little while ago that the oxygen contained in the air burns the matters in the blood, just as it burns the coal in the stove. The food has entered into the blood, as you told us; but how can the air burn it there, since air circulates only in the lungs?"

That was the very thing I was going to explain to you, but I am better pleased to see that the question came from you. This question long remained unanswered, and the real explanation of the problem is very recent.

I have already told you that the blood circulates all through the body. It must therefore *pass through the lungs, and it circulates at such a rate that all the blood of the body passes through these organs in about half a minute.* Until lately it was thought that the oxygen of the air consumed the materials of the blood *during its passage through the lungs*, and that the furnace that keeps up our heat was situated in that particular place. But it was clear that if all the heat of the body originated in that spot, the *lungs would inevitably have been* COOKED, *nay, even* REDUCED TO ASHES. Afterwards it was ascertained *that when the blood passes from the lungs it is cooler than when it enters them*, whilst evidently the contrary would have been the result had the internal fire been in the lungs.

42. Oxygenation and Blood-Corpuscles.—The production of heat takes place in a very curious manner. You remember I told you that the blood owes its rich red color to quantities of tiny red bodies or *corpuscles.* Well, *these corpuscles, in passing through the lungs,* LAY HOLD *of the* OXYGEN *of the air and* CARRY IT *along with them.* Thence they penetrate into the utmost recesses of the body, even into the capillary vessels, and in the course of their journey they *transfer to the organs through which they pass a considerable portion of the oxygen they possessed*, for which these organs have greater need and affinity than even the corpuscles themselves.

So it is ALL THROUGH THE BODY that *the consumption of oxygen takes place;* consequently the *production of heat likewise takes place* ALL THROUGH THE BODY.

43. Carbonic Acid.—As you know, the consumption of oxygen causes the formation of *carbonic acid.* This gas is

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Through what organ does all the blood of the body pass? Where was it believed that the combustion of the materials of the blood took place? What would be the consequence of this? What observation has been made on the temperature of the blood leaving the lungs? In what way do the corpuscles of blood act? Where does the consumption of oxygen take place? What gas is produced by the consumption of oxygen?

dissolved by the blood, and carried with it in the course of circulation into the lungs; there it mixes with the air, and is finally expelled at each expiration.

44. Arterial Blood and Venous Blood.—Thus the blood which the heart propels through the body by means of the arteries is more rich in oxygen than the blood brought back from the various organs by the veins.

And as it is to the oxygen that blood owes its bright red color, you can easily understand why the arterial blood is redder than the venous blood, which has a darker purplish tinge.

On the contrary, there is of course more carbonic acid in the venous blood than in that passing through the arteries.

45. Expired Air.—Thus, as you can easily understand, the *air that has passed through the lungs is by no means pure.* Before entering the body it contained one-*fifth* of oxygen; when expelled it contains only about one-*sixth*, the difference being made up by carbonic acid. You can easily understand that it must be unhealthy to breathe again the air thus altered; and it is for this reason that it is necessary to open the windows, or *ventilate*, as is said, by some means or other, the rooms in which we live.

Were an animal of any kind to be shut up in a tightly-closed box, it would certainly perish after having exhausted the oxygen of the air. Death would ensue more or less rapidly, according to the activity of its respiration, which requires a more or less rapid consumption of oxygen; a frog will live under such conditions longer than a bird; yet of necessity it also will die in time. In this case the creature is said to have been *asphyxiated*. Asphyxia comes on very rapidly under water, because the only air one has for oxygenation of the blood is the little contained in the lungs, and that is quickly exhausted.

We will now leave this difficult and arduous part of our physiological studies, and proceed to that of *sensations* and

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What becomes of this carbonic gas? What is the nature of the air that leaves our lungs? Why is it necessary to ventilate the rooms in which we live? Why must an animal that is kept in a closed box inevitably perish? What name is given to this kind of death?

will, which are certainly extremely interesting. But before doing so, if any of you has a question to ask or a remark to make, I shall be more than willing to answer and explain. What have you to say?

46. Cold-Blooded Animals.—"Please, there is something I cannot understand. You have been telling us how heat is produced in living bodies; I can easily understand this in mammalia and birds, that have *warm blood;* but reptiles, fishes, and all the small invertebrates, that have *cold blood*, do they also produce heat?"

Yes, they do; for, as they breathe, they must consume oxygen and produce carbonic acid. But the production of heat in their case is so extremely insignificant that the temperature of cold-blooded animals rarely exceeds that of the surrounding air or water. They are cold when the surrounding element is cold, warm when it is warm. Cold benumbs them so that they are sometimes unable to stir; but under the influence of heat they become almost as lively as mammalia or birds: you know how brisk and nimble a lizard becomes after basking in the sunshine. For the same reason they consume but little food in winter, their organs being but little exhausted by action, for they scarcely breathe; while in summer they burn their substance like warm-blooded animals, and eat nearly as much.

In fact, it is not at all easy to give a satisfactory answer to your question. All I can say is that all animals breathe, even those that do not seem to produce heat.

47. Aquatic Animals.—Is that all? No? Well, what do you wish to say?—"Please, animals that live in water, such as fishes and whales, how are they able to breathe?"

In the first place, you must not class whales with fishes. A whale, as I have already told you in the Natural History, is a mammal, a warm-blooded animal. True, it lives in water; but it breathes air, and comes from time to time to the surface for that purpose.

As for fishes and other really aquatic animals, what they

Do cold-blooded animals produce heat? How is it that the temperature of cold-blooded animals rarely exceeds that of the surrounding air? What do fishes do in order to breathe?

breathe is air *dissolved* in water. For water contains air, and of this I will forthwith give you proof. I set on the fire a little pan with water in it (Fig. 50). As soon as the water becomes heated, you will see tiny bubbles rise from the bottom of the pan to the surface; observe that the water is still far below the boiling-point: *these are then bubbles of air*, not of steam.

Fig. 50.—As soon as the water becomes warm you see little bubbles rising to the surface. These are not steam, but air that was dissolved in the water.

It is this air that fishes breathe; and the proof is, that they can live but a short time in water from which the air has been expelled by boiling.

They breathe by means of *gills*, or, more properly speaking, BRANCHIA (Fig. 51); that is to say, stringy, floating filaments, into which the blood penetrates, and where it comes in contact with the air dissolved in the water. Look at this gold-fish: you can see it open its mouth at regular intervals, and at the same time lift up its gills; it thus makes the air dissolved in the water pass over its branchia, just as you in breathing cause the atmospheric air to circulate through your lungs. You see, that is very simple indeed.

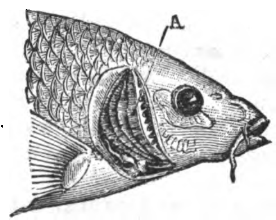

Fig. 51.—A, gills. Fishes let the air dissolved in water pass through their *gills*, thus bringing it in contact with their blood.

48. The Skin.—The skin envelops our whole body. Everywhere, except on the palms of the hands and the soles of the feet, it is covered with hairs, most of which are so small that they can scarcely be seen. When the beard grows there are no more hairs on the chin than before, but those which were there become longer and thicker.

How can you prove that there is dissolved air in water? Why does a fish die quickly when placed in water that has been boiled? In fishes what takes the place of lungs? Why does a fish regularly open its mouth and then its gills?

The skin is formed of two layers: that which is underneath is the true skin, or *derm;* that which is on the surface is the *epidermis;* this last is continually destroyed and reproduced.

You who were ill some days ago and the doctor applied a *blister*, can you tell me what happened?—"It made me better, but it hurt very much."—Yes, but that does not teach us anything. How did the blister act?—"It raised a great bubble with water in it; the doctor cut the bubble, and underneath it was all raw."—Very well: the bubble, or, as we call it, the blister, was formed of the greater part of the epidermis which was raised up and separated from the derm, and this last was raw and sensitive. Will you show us the place where the plaster was? See, it is still red, but it may be touched without hurting; a new epidermis has formed, but it is not yet as thick as the old one.

The same thing happens when one is burned, as you probably all know by experience. In the disease known as scarlet fever, or after it, the epidermis comes off in large pieces; sometimes that of the hand comes off like a glove.

When any part of the body is exposed to continued friction, the epidermis becomes thickened and hard, and so protects the derm. This is the reason that working hardens the hands.

On the surface of the skin appears, especially when one is warm, the perspiration that is formed in innumerable little glands in the derm, and it is important for the health that these glands of the skin shall act properly. There is also a sort of fatty varnish secreted by other little glands, and this it is that prevents the skin from being wetted all over when it is dipped in water. The fatty matter and the destroyed parts of the epidermis are continually accumulating on the surface of the skin, and this necessitates washings, baths; in a word, *cleanliness* of the skin. Many skin diseases are caused by insufficient attention to cleanliness, and, besides that, the uncleanly person acquires an unpleasant odor.

When the perspiration is profuse, as is often the case after

Of what parts is the skin formed? Which portion is sensitive? In which portion are the sweat-glands and fat-glands?

violent exercise or during the warm weather of summer, care must be taken to prevent sudden cooling by drinking ice-water or eating ice-cream, or by exposure to cold. For if the perspiration is arrested, colics, diarrhœa (affections of the intestines), a cold, pleurisy, or pneumonia (affections of the lungs), or rheumatism, may result.

The best thing to do, if one has been thus *chilled*, is to endeavor to start the perspiration again by going to bed and taking some hot drink, such as lemonade; or, if one is out of doors, by walking rapidly, so as to accelerate the circulation of the blood and bring up the heat of the body.

SUMMARY.—NUTRITION.

1. IN NUTRITION two functions are to be considered: 1, DIGESTION, which *dissolves* the food so that it may traverse the intestines and enter into the blood. 2, ABSORPTION into the blood.

2. Digestion (p. 28).—The DIGESTION takes place in the digestive tube, with the help of the *teeth* and under the action of the *digestive juices.*

3. Teeth (p. 29).—The *mastication* or action of chewing the food is accomplished by the *teeth,* and aided by the *tongue.*

4. A full-grown man has 32 teeth, 16 in each jaw: 4 *incisors,* 2 *canines,* and 10 *molars.* Until about the age of seven, children have only 20 teeth; the difference is in the number of molars.

5. Teeth are composed of *ivory,* overlaid with *enamel.* They are fixed in the *jaws* in holes, called *alveoli,* by one or several roots. In each tooth there is a cavity which serves as a receptacle for *nerves* and *blood-vessels.*

6. Saliva (p. 30).—The grinding of the food is facilitated by the outflow of *saliva,* a liquid formed by the *salivary glands;* tears are formed by the *lachrymal glands,* and sweat by the *sudoriparous glands.*

7. Alimentary Canal (p. 30).—The food passes down through the chest in a tube called the *œsophagus,* and reaches the *stomach.*

8. From there, the alimentary matter passes into the *small intestine,* and finally into the *large intestine.*

9. This system of tubes is called the *alimentary canal.*

10. Digestive Fluids (p. 31).—The aliments are not only passed through the alimentary canal, but there they are also TRANSFORMED, under the influence of *juices* or fluids supplied by different glands.

11. The first of these juices is the *saliva,* which transforms flour into *sugar.*

12. The *gastric juice* secreted by the stomach dissolves flesh, albumen, and in general all animal substances except fat.

13. The aliments which have escaped the influence of the saliva, and the gastric juice, are dissolved by the glands of the small intestine, of which the most important is the *pancreas.*

What is the danger of suddenly arresting perspiration?

14. The *liver*, another very important gland, situated to the right in our body, is the organ in which *bile* is produced. The blood is purified in passing through the liver by giving off those substances which constitute the bile.

15. Absorption (p. 33).—The food, rendered liquid, passes through the tissues of the intestine and mingles with the blood. The blood then carries it all through the body: this is what is called ABSORPTION.

16. The hygiene of digestion consists in cleanliness of the teeth and attention to the quantity and kind of food taken.

17. Impure water may produce typhoid fever.

18. Medicines, including stimulants and narcotics, should be taken only on the advice of a physician.

19. Blood (p. 36).—Blood is a *yellowish* liquid in which float an extraordinary number of very little *red* corpuscles.

20. Circulation (p. 37).—The blood is sent all through the body by means of a hollow muscular organ called the *heart*, which contracts regularly: each *contraction* or beat sends out into the arteries a gush of blood.

21. The blood is conveyed to the heart by soft tubes called *veins*, and leaves the heart by others much more rigid, called *arteries*.

22. All the arteries *divide* and subdivide, finally forming minute *capillaries;* these *reunite* to form larger and larger vessels, called veins. It is in all these that the blood flows or is said to *circulate*.

23. Thus the blood passes from the heart to the arteries, from the arteries to the capillary vessels, from the capillary vessels to the veins, and from these back to the heart, and all this is accomplished by the impulse imparted by the heart after each contraction. This is what is called the CIRCULATION.

24. The *pulse*, which one can easily feel at the wrist or at the temple, is produced by the shock of the blood in the arteries, which, at these places, are quite near the skin.

25. Oxygenation (p. 39).—The blood carries off the dissolved alimentary matters, and deposits a certain part of them all through the body; the rest is *consumed* in the blood itself.

26. This combustion maintains in our body a temperature of 98°.

27. The factor necessary for this combustion is the *oxygen* contained in the air we breathe; it produces the *carbonic acid gas* which is cast out.

28. Breathing (p. 40).—The air we breathe passes through a tube called the *trachea* (windpipe) and penetrates into the LUNGS.

29. The lungs are hollow organs; they are formed by a number of tubes called *bronchia*.

30. About fifteen times every minute the chest, which is closed below by the *diaphragm*, expands, thus inhaling the *surrounding* air: this is the act of *inspiration*. Subsequently the chest lessens in capacity, so that the air is expelled: this is the act of *expiration*.

31. By means of what is called the circulation of the blood, all the blood of the body *passes through the lungs* in half a minute; the corpuscles of the blood lay hold of the oxygen of the air at each inspiration and carry it along with them to the utmost recesses of the capillary vessels. In the course of this journey they give up a great part of this oxygen to the organs they permeate.

32. In this manner the oxygen is consumed all over the body, and not

in the lungs only: therefore heat is produced likewise all through the body.

33. An animal deprived of air perishes, *asphyxiated*.

34. The air which our lungs reject is not pure, for it contains carbonic acid: therefore it is necessary to ventilate our dwellings,—that is, renew the air in them.

35. Cold-blooded animals also consume oxygen, since they breathe; but the production of heat which ensues is so very small that the temperature of their bodies rarely exceeds that of the surrounding medium.

36. By means of their *gills* fishes breathe the oxygen that exists dissolved in the water.

37. The skin envelops the whole body. It is composed of an inner layer, the derm, and an outer layer, the epiderm, which wears away and is renewed.

38. The perspiration-glands are in the derm, together with fat-glands, and the products of these glands must be removed from the skin by washing.

39. It is important that profuse perspiration should not be suddenly checked, lest colic, diarrhœa, a cold, or rheumatism result.

[Simple *Subjects for composition* are to be found at page 68.]

III.—SENSATION.

49. You remember the simple experiment in which we so frightened the poor chickens by suddenly opening the window. What enabled them to hear the noise of the window? Their ears, was it not? And how were they enabled to perceive your presence that so terrified them? With their eyes, of course. And with what were they able to flee from the danger? With the muscles of their limbs. And with what were they able to understand that they were menaced, and to command the movement that was to carry them to a place of safety? Ah! you are unable to answer this time. Well, I will tell you. It was with their BRAIN.

But the brain is in the cavity of the skull, the eye is in its socket, the ear is in a hollow of the skull, the muscles of the limbs are far removed in the lower part of the creature. What can put the *eye* and the *ear* in communication with the *brain*, and the *brain* with the *muscles?*

50. Nerves.—*Communication is established by what physiologists call* NERVES. These nerves are exceedingly fine white

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How do the eye, the ear, and the muscles communicate with the brain? What are these nerves?

threads which pervade all parts of the body. Some carry *to* the brain *the sensations that come from* WITHOUT, and their little branches are so numerous that it is impossible to prick any part of your skin with the very finest needle without injuring one of them and without feeling a sensation of pain; others convey *orders of* MOTION *from* the brain to the muscles of the whole body.

The former are called SENSORY *nerves*, and the latter MOTOR NERVES.

51. Spinal Cord.—The nerves do not end directly in the brain. All those that exist in the body and in the limbs communicate with the SPINAL CORD (Fig. 52). This spinal cord or marrow is, as its name indicates, a sort of cord, externally of a whitish color and grayish internally; it is situated in the canal of the vertebral or spinal column, which canal is on that account often called the *medullary canal* (from the Latin *medulla*, marrow).

Between every two ver-

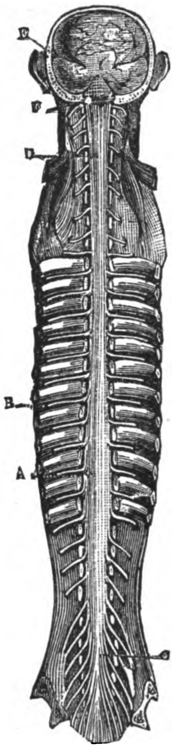

FIG. 52. A, the medullary canal.
B, a nerve, passing out between two vertebræ, to be distributed to the adjacent parts.
D, C, spinal cord, from which the nerves of the body and limbs take their rise. It is enclosed in the spinal canal.
E, brain.
F, medulla oblongata, from which the nerves of the face and head arise, as well as those that preside over the movements of the heart and lungs.

There are two kinds of nerves: to which do they belong? What name is given to nerves of the first kind? To those of the second kind? Where do all the nerves that exist in the body and limbs start from? Where is the spinal cord placed?

tebræ there shoot forth, to the right and to the left, **nerves** B, each of which goes to some allotted part of the body.

At C, in the lumbar region, the marrow tapers off to an end. In the superior regions at F it passes into the **skull**, swells out, and becomes what is called the MEDULLA OBLONGATA. *The nerves of the face and of the head, and also those that preside over the movements of the heart and of the lungs, arise from this medulla oblongata.* This allows you to understand the extreme gravity of a wound in the medulla oblongata, and why a fatal issue is always inevitable in a very short space of time. For it checks both the CIRCULATION OF THE BLOOD and the RESPIRATORY MOVEMENTS. Into this medulla oblongata cooks sometimes drive a long pin when they wish to kill their poultry instantaneously, and this is what is wounded and even severed by dislocation when they strike the fatal blow close behind the ears of a rabbit.

52. The Brain.—Almost the whole cavity of the skull is filled by the BRAIN. It is a large pulpy mass, gray externally and white inside, and in mankind and in many of the mammalia is covered over with sorts of folds called *convolutions.*

It is in the brain that INTELLIGENCE *resides*, that SENSATIONS are perceived and IDEAS *formed*, and *that* WILL *originates.* The more intelligence an *animal* has, the more brain it possesses. In mankind, when the weight of the brain is less than two pounds, the person who is so scantily provided is an idiot. If the brain is wounded, intelligence is weakened, and the sufferer becomes mad or insane: this happens, also, after certain diseases. In some cases such wounds, however, may heal, and the intelligence recover partially, if not totally.

If the brain be destroyed, no trace of intelligence will remain. Such a thing has come under notice in the case of some birds whose brain alone was wounded, the medulla oblongata being uninjured. Being carefully nursed, their lives were saved, but both *intelligence* and *will* had completely

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Between what parts of the vertebral column do the nerves pass out? What name is given to the spinal cord at the place where it enters the skull? What nerves take their origin in the medulla oblongata? Why is a wound in the medulla oblongata mortal? By what is the cavity of the skull filled? Of what faculty is the brain the seat? What happens when the brain is wounded?

disappeared. *The brain gone*, the bird will remain on its perch without ever having the idea of moving or seeking food. Nay, it would die of hunger beside heaps of food without ever thinking of eating; but if food be put into its beak it will unconsciously swallow and digest it as if nothing had happened. If flung into the air, it quite unconsciously spreads out its wings and flies right onward, until it meets with some obstacle or drops down exhausted. Birds in this condition have been known to be kept alive for months, their guardians having nursed them by putting food into their throats. During all the time they continued to live in this condition they never gave the slightest sign of intelligence or will. Let us now pass on to sensations.

53. The Sense of Touch.—First, we may mention the *general sensation* of TOUCH, which lets us know that some object is in contact with our body. All the surface of the skin is endowed with this; also the lining of the mouth, of the nose, the eye, the ear, etc. Over all this surface are spread small branches of the *sensory nerves*, which, when excited, transmit the sensations they receive to the *spinal cord*, and thence to the *brain*, just as an electric wire transmits a telegram.

When these nerves warn us that something has touched us, they tell us at the same time if we have come in contact with something *colder or warmer* than *our body*, and also inform us approximately of the proportion of cold or heat: we have thus the *sensation* of TEMPERATURE.

Both these sensations—that of temperature and that of contact—are generally included under and expressed by the general name of FEELING or TOUCH.

Feeling can really be said to exist only when our INTELLIGENCE ENTERS INTO ACTION in order to make use of the sensitive powers of our skin. Generally it is with the HAND that we touch or feel things. This five-armed compass, which *man alone possesses*, is a most marvellous instrument, not only with which to grasp powerfully or handle delicately, but

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What happens when the brains of certain animals are removed? On what parts of our body does the sensation of touch take place? To what is the sensibility of our skin due? What other sensation is given us by the nerves that reach our skin? With what do we generally exercise the sense of touch?

also to give a pretty accurate idea of the body it touches. See, here is an apple. I lay my forearm on it (Fig. 53). You will easily believe that were I blindfolded it would cost me very much time and many trials to ascertain, by means of feeling with the skin of my forearm alone, that I had to deal with a rather hard, round, and polished body; but

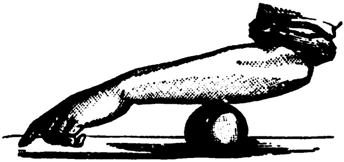

FIG. 53.—With the forearm it requires time to perceive that an apple is a round, polished, and resisting body.

FIG. 54.—It suffices to take it for an instant in my hand, to perceive all that.

I should find out all those facts in an instant were I to take the apple in my hand (Fig. 54), because I should bring a great many points of its surface in contact with my skin.

54. The Sense of Taste.—The mouth is capable of exercising a sort of feeling called TASTE. The substances we put into our mouth, if capable of melting or dissolving, produce particular impressions, known by the name of tastes or *savors*. Everybody knows about them, and we all understand what is meant by a sweet, or a salt, or a bitter taste. Some people spend their lifetime in efforts to satisfy this one sense of taste. The culinary art has been invented in order to satisfy it within reasonable limits; and that very properly, too, for experience has proved that, generally speaking, food which is agreeable to the palate is easily digested. The nerves of taste are most highly sensitive in the tongue.

55. SENSATIONS AT A DISTANCE.—But, setting aside the very limited notions which the sense of *taste* furnishes to us, you see that *touch* tells the shape of bodies, their hardness, their polish, their temperature, and several other properties.

This is undoubtedly a great deal; but had we only that

Name a certain variety of touch, the seat of which is in the mouth. What name is given to the impressions furnished by the taste?

we should be rather poorly informed. Fortunately, even at a distance we can detect the presence of objects by SMELL, by HEARING, and especially by SIGHT, which last alone might almost supply the place of all the others.

56. The Sense of Smell.—The *olfactory* organ is the *nose*, or, more properly speaking, the *nasal chambers*. These are two cavities A, B (Fig. 55) separated by a vertical partition C; the cavities open in front by the nostril and behind into the throat D, opposite the opening of the larynx E. During

FIG. 55.

Section of the nose, seen from the front. Section of the nose, seen from the side.
A, B, nasal chambers. D, back of the throat.
C, vertical partition. E, opening of the larynx.

respiration under ordinary circumstances the air passes by this channel. There are even some animals, as I have already told you, that breathe exclusively through the nose; and were the nostrils of a horse to be closed, that animal would very rapidly die from asphyxia, or privation of air.

During inspiration smell makes us aware of the proximity of certain bodies which, for reasons as yet unknown, have the faculty of making impressions upon our olfactory organ, and are, as it is called, *odorous*. Unfortunately, as we have already seen in former lessons, some very noxious gases have no odor whatever, so that we might be poisoned by inhaling them unawares.

57. The Sense of Hearing.—*Hearing* informs us, as you know, of the existence of *sonorous vibrations*. It teaches us,

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Name the senses which at a *distance* inform us of the presence of other bodies. What is the organ of smell? What do you call the *chambers of the nose?*

moreover, to measure and appreciate them, for with practice, and when one is particularly gifted, it is possible to distinguish exceedingly slight variations in sounds. We have already seen in physics that our ear cannot detect a sound unless the number of vibrations exceed 32 per second. This is the *very lowest sound* that can be heard by us; the *highest* is produced by 76,000 vibrations per second.

Vibrations coming from without can be transmitted to the AUDITORY NERVE in two different ways: when we have to

FIG. 56.—Stop your two ears. I place my watch on your forehead: you clearly hear the tick-tick.

FIG. 57.—Take the watch between your teeth: you still distinctly hear it.

FIG. 58.—I place my watch on a flat ruler: you still hear it.

deal with the vibrations of a solid body we perceive them by simply laying the body close to our head.

Come here, and stop up your ears closely with both hands (Fig. 56). I will put my watch against your forehead, and you will hear quite distinctly its tick-tick. Open your mouth now, and take the watch between your teeth (Fig. 57): you will still hear it very well. Now take this flat ruler between your teeth (Fig. 58): I lay the watch upon it, and the result is the same.

In this last experiment the sonorous vibrations produced by the works of the watch have set in motion successively the watch-case, the ruler, the teeth, the skull-bones, the liquid of the ear, the terminations of the auditory nerve, and thence have reached the brain.

But direct transmission such as this is very rare. In the

What does hearing teach us?

great majority of cases sound is produced by the vibrations of a body separated from us by *air*. In this case it is the vibrations communicated by the air to our ear that must be detected and heard. This requires considerable complication of the auditory organ.

58. The component parts of the ear are, first the *pinna* A (Fig. 59). This external part is very much developed in animals of acute hearing, which turn and direct it so as to catch the greatest possible quantity of sound. The horse (Fig. 60), for instance, pricks up his ears, turning them towards the direction from which the sound comes. Our *pinna* is of but little importance and almost motionless; it is of some use, however, and we turn it to catch the sound, only the whole head turns along with it; when the sound is not sufficiently strong, sometimes we even place our hand around the ear behind the pinna, thus making a sort of ear-trumpet.

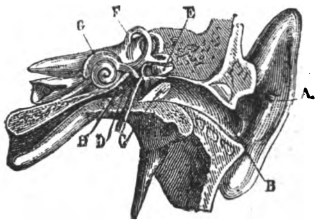

FIG. 59.—Auditory apparatus.

A, pinna.
B, auditory meatus.
C, membrane of the tympanum.
D, cavity full of liquid.
E, chain of small bones.
F, semicircular canals.
G, cochlea in connection with the auditory nerve.
H, membrane of the cavity full of liquid.

By the pinna, vibrations are gathered together and introduced into a passage B, called the *auditory tube* or *meatus*. In mankind it is but a few inches in length. At its base C the vibrations come in contact with a sort of thin skin, stretched across the auditory passage, which it closes up: this skin is the *membrane of the tympanum*, commonly called the *drum* of the ear. This membrane is also set in vibration in its turn.

Here we come to a very curious and interesting part of the auditory function. There is an interval of about an inch be-

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What name is given to the external part of the ear? What name is given to the tube which is continuous with the pinna? What do the vibrations meet with at the bottom of the auditory tube? What name is given to this membrane? What is there between the tympanum and the internal cavity full of liquid that has to be put in motion?

tween the membrane of the tympanum and the cavity D full of liquid, which has next to be set in motion. This bony cavity has an opening closed up by a second outstretched membrane.

Fig. 60.—The horse directs his ear towards the point of origin of the sound.

Now between this last-mentioned membrane and that of the tympanum there exists a chain of tiny bones or ossicles E, and the ends of the chain are in contact with the two membranes. This arrangement allows the vibration of the membrane of the tympanum to be transmitted to that of the cavity, thence to the liquid, and lastly to the auditory nerve G.

In short, if we recapitulate we shall find that the sound takes the following course: air, membrane of the tympanum, ossicles, membrane of the cavity, fluid of the cavity, nerve. Thus the vibrations have passed successively through gases, solids, liquids. You see what a complicated thing hearing is; and yet I have omitted a great many very interesting details.

59. The Sense of Sight.—Now let us consider the eye, the organ of sight, or *visual sensation*. It is a most delicate organ, but its mechanism is more easily understood than that of the ear, and I shall be able to show you all the principal parts of this important organ with the help of this ox eye which the butcher gave me (Fig. 61).

You can observe that it bears no little resemblance to an egg the shell of which, although pretty hard, is not calcified. At the tip of this shell, you find this white string: it is the OPTIC NERVE, the nerve that conveys to the brain the impressions made upon the eye by light; it penetrates, as you see, into the eye; and now we will follow it and ascertain what becomes of it.

Indicate the course the vibrations must take. Where does the optic nerve terminate?

The outer coat of the eye G is opaque, except in the front part A, where it becomes transparent so as to allow the light to enter.

This transparent part is called the CORNEA.

The light passes through this cornea A; but before reaching the back part of the eye, and after having run through a little chamber B full of liquid, it falls upon a sort of curtain C called the IRIS, which is stretched out and has in the centre an opening D called the PUPIL. Come here near the window, Henry; and all of you stand around him and be attentive. Henry's eyes are blue; that is to say, the little curtain, the *iris*, is of a blue color. In the centre of the iris D you see a small round hole, quite black. That is the *pupil:* through it the light passes into the eye.

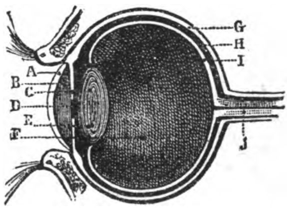

FIG. 61.—The eye, organ of vision. Section of the eye of an ox.

A, transparent cornea.
B, anterior chamber full of liquid (aqueous humor).
C, iris.
D, pupil.
E, crystalline lens.
F, sticky liquid (vitreous humor.)
G, globe of the eye (sclerotic).
H, choroid.
I, retina.
J, optic nerve.

Now wait a little; I will close Henry's eyelid for a short time, then suddenly open it again. Did you observe what took place? The little black hole was *very large* (Fig. 62) immediately after I lifted the eyelid; as soon as the light reached it it became small (Fig. 63). Now you see it is quite small, almost a speck. Let us now go to the farther end of the school-room, where the light is less strong. See, the pupil enlarges again. What does this mean? Oh, you will all easily follow the explanation. When there is *but little light, the pupil widens out*, so as to gather in as much as possible; when, on the contrary, *the light is strong, it draws itself in,*

Is the entire outer coat of the eye opaque? What name is given to the transparent part? What does the light meet with after having traversed the cornea? What name is given to the little hole which is in the iris? Where does the light enter the eye? Why is the pupil large when there is only a little light? and why is it small in a strong light?

allowing only the necessary quantity to pass through, thus keeping the optic nerve from being fatigued, or *dazzled*.

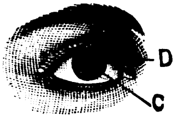

FIG. 62.—C, iris; D, pupil, large in a dim light.

FIG. 63.—C, iris; D, pupil, small in a bright light.

There, we have seen how the light gets into the eye. Now we must follow it and see how it goes on. For this purpose the ox's eye (Fig. 61) will be most useful. Here it is cut open lengthwise. See, the globe of the eye is filled F with a sort of sticky but very transparent liquid. You can easily recognize the cornea A, and the curtain C of the iris. And now, just behind the pupil D, look at this rather hard, transparent body E, shaped exactly like a magnifying-glass: it is the CRYSTALLINE LENS.

All over the back part of the interior of the eye is spread a sort of grayish membrane I, very easily torn. This is the RETINA; it is formed by the termination of the optic nerve in the eye. It is this retina that receives impressions from the light, and on it the images of surrounding objects are formed.

How can this take place? If you have kept in mind the experiment we made in the *dark chamber* you will have no difficulty in understanding it. We will, however, repeat it once more. Let us go into our *dark room* (Fig. 64). Here is a small hole B through which passes a ray of light. I place my lens C over this, and on the opposite wall D I fix a sheet of paper. After some focussing, we can manage to arrange things so that the image of the neighboring church is to be seen on the paper. You are aware of that.

Well, the shutter A plays the part of the *iris;* the hole B in the shutter, that of the *pupil;* the lens C, that of the

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With what is the globe of the eye filled? What is found just behind the pupil? What is the retina which lines the back of the eye? In what way is the retina acted on? Compare the different parts of a dark room with the different parts of an eye.

crystalline lens; the sheet of paper D, that of the *retina.* Such is the phenomenon of vision reduced to its most elementary expression.

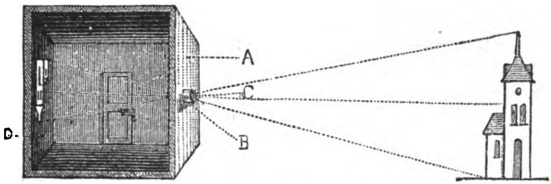

FIG. 64.—Dark room.

The shutter A is the iris.
The hole B of the shutter is the pupil.
The lens C is the crystalline lens.
The sheet of paper D is the retina.

60. Short-sighted and Long-sighted Persons.—In the course of our experiment you have observed that a distinct *image was obtained* only when I placed my sheet of paper at a certain distance from the shutter; the paper was then, as I have already explained to you, in focus. When it was either too near or too far off, the reflected image was dim and not very clear.

Now, it sometimes happens that a person's eye is either a little too shallow or a little too deep. When it is too deep, the image falls in front of the retina, and the person whose eyes have this defect is said to be *myopic*, or *short-sighted;* when, on the contrary, the eye is too shallow, the image falls behind the retina, and the person having this trouble is said to be *presbyopic*, or *long-sighted.*

Both these defects in the sight can be obviated by the use of spectacles, those intended for short-sighted people having *concave* glasses, which move the image backward, while long-sighted people require *convex* glasses, which bring the image forward. In each of these cases a distinct image is then produced upon the retina.

The sense of sight is the most precious of all. It acquaints us with the shape and the dimensions of bodies, and lets us

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What name is given to persons who can see objects only when placed near the eye? And to those who can see well at a distance only? With what kind of spectacles are near-sighted persons relieved? And long-sighted?

know at what distance they are. It also gives us notions of colors.

61. False Sensations.—All this is undoubtedly very marvellous and admirable. Nevertheless the eye is by no means a perfect instrument. Nay, it would often lead us into error, did we not rectify by our reason the false impressions it sometimes gives us. In some cases, even, we cannot altogether correct them. I will give you an example.

You have not forgotten the colors of the *spectrum:* violet, indigo, blue, green, yellow, orange, red. Let us single out the green, for example. Well, the same green may be obtained, that is, the same sensation of green, by examining the green of the spectrum alone, or by combining in due proportion blue and yellow. Likewise, we can artificially obtain a violet color by mixing together red and blue, and an orange with red and yellow. The eye is in this case completely deceived, and deceives us at the same time, for it does not enable us to detect the slightest difference between a *simple* and a *compound* color.

62. Reasoning.—Were we in possession of sight alone we should fall into many more errors. But hearing, and especially touch, help us to rectify our mistakes. Upon the whole, all these different sensations send information to our brain, and enable us to form a pretty accurate idea of what is going on around us. Thereupon *our brain reasons*, and induces us to make use of all that is good for us, to avoid what would harm us, and so to act as to improve even nature by countless inventions and industries. A dog's senses are as keen as ours; the sense of smell is in his case infinitely more acute; and yet he cannot make use of all his powers for improving his situation or making progress, *because he is not endowed with sufficient intelligence.* Some people say that the cause of his inferiority is lack of hands and speech. But had he ten hands he could not utilize them as we do. And if he does not speak, it is because he is incapable of inventing words. Idiots have hands, and often they can speak.

Why is man superior to the other animals?

It is neither the hand nor the tongue that makes man what he is: it is his intelligence and his brain.

63. Nervous Derangements.—I have already told you that those who pass their lives shut up in houses and offices are not often strong. Their muscles are not thick and hard, and their blood is not rich. But, worse than that, they make their brains and their nerves work too hard; they fatigue their heads and become irritable, or *nervous*, as it is called, being excited to gayety or anger without sufficient cause. Sometimes, indeed, their brains become altogether deranged, and are no longer able to act properly; the persons are then *insane*, or *lunatic*. It is by no means true, however, that the professions and sedentary occupations furnish all the cases of insanity and deranged nerves. Nervous derangements are, unhappily, too common, and are brought about by various causes.

A frequent source of nervous disease, and even of insanity, is poisoning by alcohol and tobacco. These substances are not foods, for they are incapable of sustaining life: they be-

FIG. 65.—Be sober, and you will be well.

FIG. 66.—Dissipation affects the brain, and gives a degraded expression to the countenance.

long to the substances called *stimulants* and *narcotics* from their peculiar effects on the nervous system. Among stimulants are included tea, coffee, alcoholic liquids, tobacco, and

What results from giving the brain too much work to do? What is the effect of alcohol on the nervous system?

opium, which is a poisonous drug obtained from the poppy-plant. In some countries this drug is used as a sort of stimulant; those who use it rapidly become deprived of the powers of body and mind by the mischievous action of the poison. The effects of tobacco are due to an exceedingly violent poison, nicotine, which it contains in small quantity. You all know the terrible effects of spirituous liquors; and one of the saddest results that they produce is the destruction of the will-power which enables man to control his actions. All stimulants, even tea and coffee, are especially injurious during the processes of bodily growth,—that is, to children.

FIG. 67.—These boys want to be "men;" they *smoke*, and injure their health.

Cerebral Congestion.—When too much blood is supplied to the brain, headache and giddiness result; this is called cerebral congestion, and is not very dangerous. But sometimes the blood forces its way out of the small blood-vessels in the brain, producing a cerebral hemorrhage. Usually in this affection the person loses the use of part of his body; *paralysis* results, and sometimes death follows. While waiting for the doctor in cases of cerebral congestion, the head should be kept elevated and the clothing loosened, so that the circulation in the body may not be impeded. Cloths wet with cold water may also be applied to the head.

SUMMARY.—SENSATION.

1. **Nerves** (p. 52).—NERVES are delicate white threads that pervade the whole body.

2. Some carry to the brain sensations that come from without: these are *sensory nerves*.

3. Others convey orders for motion from the brain to the muscles throughout the whole body: these are *motor nerves*.

4. **Spinal Marrow** (p. 53).—The SPINAL MARROW or spinal cord is a sort

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When are stimulants especially injurious? What is meant by cerebral congestion?

of white cord hidden in the canal that runs through the vertebral column, which canal is formed by superposed rings.

5. At the spot where the spinal cord penetrates the skull, it widens and becomes what is called the MEDULLA OBLONGATA.

6. The nerves of the body originate in the spinal marrow; those of the head, together with those that rule over the movements of the *heart* and *respiration*, arise from the medulla oblongata. Injuries to the medulla oblongata are inevitably fatal.

7. The Brain (p. 54.)—The cavity of the skull is almost entirely occupied by the BRAIN.

8. It is in the brain that *intelligence* resides, there it is that *sensations* and *ideas* are formed, there also that *will* originates.

9. Injuries to the brain, if not fatal, entail a weakening of intellectual power.

10. A bird may live although deprived of its brain, if all its wants be carefully supplied; it will inevitably die if any harm reach its medulla oblongata.

11. The Sense of Touch (p. 55).—The general sensation of *touch* warns us when some object has come in contact with our body.

12. This sensation can be transmitted by any part of the body, but more particularly by the hand.

13. Tactile impressions are transmitted by the *sensory nerves*, whose terminations are beneath the surface of the skin, to the spinal marrow, thence to the brain.

14. These nerves also impart to us the knowledge of the *temperature* of bodies.

15. In the mouth there exists the peculiar sort of *touch* called *taste*, which gives us impressions of *tastes* or *savors*.

16. Sensations at a Distance (p. 56).—The sense of touch informs us only of objects with which we come in contact; *smell*, *hearing*, and especially *sight*, tell us of what is at a certain distance from our body.

17. The *organ of smell* is the *nose*, or, more precisely speaking, the *chambers of the nose* that open into the throat opposite the entrance of the larynx.

18. *Hearing* acquaints us with what are called *sonorous* vibrations.

19. The Ear (p. 57.)—The vibrations received by the *pinna* of the ear travel along the *auditory tube*, at the extremity of which they come in contact with the *membrane of the tympanum* and set it in motion. The vibrations of the membrane of the tympanum are transmitted by a chain of *little ossicles* to a *second membrane*, which closes up a cavity full of liquid. This liquid in its turn transmits the vibrations to the *auditory nerve*, which carries them to the *brain*.

20. The Eye (p. 60).—The *eye* is a sort of globe, transparent only in its front part, called the *cornea*. Behind the cornea is a sort of curtain called the *iris*, which is sometimes gray, sometimes blue or brown, giving to the eye its peculiar tint. This curtain is pierced with a central opening, called the *pupil*, through which light enters into the eye, after having passed through a sort of magnifying lens called the *crystalline lens*, placed just behind the pupil. The light then passes through the transparent fluid which fills the globe of the eye, and falls upon the *optic nerve*, which under the name of the *retina* overspreads the interior surface of the back part of the eye.

21. Reasoning (p. 64).—Had we only our eyes and the other organs of senses to direct us, we should be led into error in many cases. Our brain surveys all, however, being called into action by our organs of sense: it reasons and teaches us to take advantage of things that are useful, and to avoid those that would do us harm.

22. It is neither the hand nor the tongue that makes man what he is: it is his intelligence, and his brain.

23. Nervous derangements, even insanity, may result from overworking the brain and nerves.

24. The same effects are frequently produced by poisoning by alcohol and tobacco.

SUBJECTS FOR COMPOSITION.

1st Composition (p. 11).—Composition and structure of bone. Of what use is the marrow of the bones?

2d Composition (p. 12).—What a vertebra is. The different regions of the vertebral column. The appendages of the vertebræ of the dorsal region. The manner in which the ribs are united in front. Five vertebræ united constitute the sacrum. What bone is supported by the sacrum?

3d Composition (p. 14).—By what is the skull supported? The interior of the skull and its communication with the vertebral canal. The cavities of the skull. The two jaws.

4th Composition (p. 15).—The bones of the upper or fore limbs and of the hand. Which bone articulates with the humerus? With which bone does the scapula, or shoulder-blade, articulate? with which the clavicle, or collar-bone?

5th Composition (p. 16).—The bones of the lower limbs. Upon which bone does the *femur* articulate? To which bone is the pelvis attached?

6th Composition (p. 17).—Describe an articulation. What insures the solidity of an articulation? When is a joint said to be sprained? when dislocated? Fractures; how they become mended.

7th Composition (p. 19).—Of what use are muscles? In what manner are the muscles frequently fastened to the bones? Muscular contractility. Muscles of the forearm.

8th Composition (p. 23).—Show how it is that we should not be able to stand erect were it not for the help of the muscles.

9th Composition (p. 24).—Voluntary movements, involuntary movements.

10th Composition (p. 29).—The teeth, their names and their number. The different parts of a tooth.

11th Composition (p. 31).—What becomes of the aliments in passing through the alimentary canal?

12th Composition (p. 32).—Part played by the saliva, by the gastric juice, by the intestinal juices, by the pancreatic juice. The liver. The aim of digestion. Hygiene of digestion.

13th Composition (p. 33).—Part played by the blood. By what organ it is impelled through the blood-vessels. Arteries. Veins. Capillary vessels. Circulation.

14th Composition (p. 39).—Into what do the aliments pass after digestion has liquefied them? What becomes of them? What maintains our temperature almost invariably at about 98° Fahrenheit?

15th Composition (p. 40).—How does the air penetrate into our body? The lungs. Respiratory movements.

16th Composition (p. 45).—By what process is the oxygen of the air consumed in our body? Production of carbonic acid.

17th Composition (p. 48).—How do fishes breathe?

18th Composition (p. 53).—The brain. Spinal marrow. Medulla oblongata. What happens to birds in which the brain has been destroyed?

19th Composition (p. 55).—Touch. Taste. Sensations produced at a distance.

20th Composition (p. 57).—The nose.

21st Composition (p. 57).—The ear.

22d Composition (p. 60).—The eye.

23d Composition (p. 64).—Man's intelligence.

24th Composition (p. 65)—Causes of nervous derangements.

25th Composition (p. 66).—Effects of the abuse of stimulants on the body.

VII.—VEGETABLE PHYSIOLOGY.

64. Vital Acts are similar throughout all the Animal Kingdom.—We know how animals live, how and why they eat and breathe, how they move about, how they feel, and how they show will-power. I say "animals," although I have scarcely spoken of any except the vertebrates, scarcely even of mankind, because in reality we meet with essentially the same phenomena in all. When a beetle flies, it sets its wings in motion by contracting its muscles, just as we do when we set in motion our arms, etc. True, the beetle has no bones affording to its muscles a point of support, but its hardened skin answers the same purpose. A snail draws in its horns on being touched because it feels the contact of your finger by the mediation of a nerve, just as we feel by the sense of touch. When a butterfly that you try to catch looks at you and flies away to escape from you, it reasons in its little brain just as the chickens did when you frightened them. An animal may have four feet, or six, or two, or even none at all, it may feed on grass or on flesh, it may live hidden in a hole, or under the deep water, or it may soar in the open air above the clouds, the great question with it ever is to eat enough to replenish what its organism has used, to feel, to move, to will; it is always a matter of stomach, muscles, nerves, and brain.

We must now try to see *how* PLANTS *live*. At first sight this study seems less interesting than that of animal life, because plants have no power of locomotion, neither have they feeling nor will; consequently they have no muscles, nerves, brain, nor sense-organs. But they require food, they grow, and in this respect they afford, as I will hereafter show you, even a still more curious study than animals.

We will begin by what is most astonishing in our subject, —namely, the *development*.

65. Germination.—Once more we will consider the ordi-

nary bean (Fig. 68), that has already been so useful in our botanical lessons (see Botany); I will again show you the parts that compose this seed; so we will in the first place take off the skin, which for us has no great importance. This discloses to you two fleshy masses A, B, the *cotyledons;* between these you see the young plant C, with its radicle or rootlet below, its tiny plumule above.

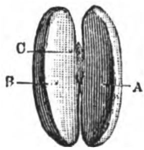

FIG. 68.
A, B, cotyledons.
C, young plant.

Here is another bean (Fig. 69), in which the radicle projects about an inch from the cotyledons D, E; the stem B also has stretched out, and begins to unfold tiny leaves C. This bean has begun to SHOOT.

66. Conditions necessary for Germination.—You wish to know how this result was obtained. Some days ago I put the bean into a pot among some damp pounded bricks. The moisture swelled up the skin of the bean, soaked the young plant, which drought had kept asleep as it were, and thus awoke it.

So the plant grew.

FIG. 69.—A bean that has germinated, thanks in the first place to moisture, in the second to heat, in the third to the oxygen of the air.
A, radicle.
B, stem.
C, young leaves.
D, E, cotyledons.

MOISTURE, *then, is an indispensable condition of* GERMINATION. When one desires to keep seeds for any length of time, they must be carefully stored in some *dry place*, otherwise they begin to shoot. That is a fact every one knows.

You must not conclude, however, that moisture alone suffices to induce germination. If it were winter, and if the bean, even moistened, had been kept at a temperature but a few degrees above the freezing-point, it would not have begun to shoot; at *fifty degrees Fahren-*

What condition is necessary to germination? What precaution must be taken when we wish to prevent seeds from germinating? Does moisture alone suffice for germination?

heit the germination would have been but very slow. But it is spring-time, the thermometer of the school-room indicates 68 degrees Fahrenheit; therefore the germination has gone on rapidly. Besides moisture, then, a *certain degree of* HEAT *is necessary in order to allow seeds to germinate;* and the greater the heat, the more rapidly do they shoot up, —this in a moderate measure of course: it would be quite a mistake to have them cooked, if you desire them to grow.

This is not all. *The bean* I show you *began to shoot because it was* IN AIR. Had I put it under water it would not have done so, even had it not lacked heat. It requires, then, air also. And, as you can easily imagine, *what it requires from air is* OXYGEN. It can perfectly do without nitrogen, but it greedily *absorbs* the oxygen, it *breathes* oxygen, and gives back *carbonic acid* just as an animal would.

FIG. 70.—The flame goes out immediately because the oxygen in the bottle has been absorbed by the seed that has germinated.

See, here is a closely-corked glass bottle (Fig. 70), into which I a few days ago put some barley-seeds moistened so that they might shoot. They have grown a little, as you see, then died *because all the oxygen that was in the bottle was exhausted.* See, here is the proof of what I say. I set fire to this bit of straw and plunge it into the bottle: the flame goes out immediately, because there is no oxygen. If I had the proper apparatus here, I could show you that what has taken the place of the oxygen is simply carbonic acid.

So, *the seed in the course of* GERMINATION *consumes oxygen and produces carbonic acid; its respiration is similar to that of an animal.*

But carbonic acid is produced by combustion of CARBON in oxygen. Where does the seed find the CARBON it thus burns?

What more is needed? What else is wanted to enable our bean to sprout? Does it take from the air oxygen or nitrogen? In short, what does a plant do in germination?

67. Consumption of Carbon during Germination.—Observe the cotyledons of this bean: they are flabby, shrivelled, and half empty, instead of being round and fleshy as before. *It is they that have furnished the carbon.* They contained starchy matters, rich in carbon, and these have disappeared to such an extent that the bean has become unfit for eating.

68. Vegetation in the Dark and Vegetation in the Light.—This source of carbon cannot last a long time. Here is a bean (Fig. 71) that I planted about a fortnight

FIG. 71.—A bean that has germinated in the *dark:* it is yellow, and has lost in weight, having lived only on the carbon of the two cotyledons.

FIG. 72.—A bean that has germinated in the *open air:* it is green, its weight has increased; it has lived on the carbon that it took from the carbonic acid of the air.

ago, at the same time as another I will soon show you. I planted it in pounded, moistened brick, but instead of leaving it exposed to the light I kept it in the *dark.* It has grown quite yellow, as you see; it is, as we say, *etiolated.* See, its stalk is about twenty inches long. And were I to dry the entire plant, leaves, stem, and what remains of the bean itself, you would see that the whole *weighs much less* than a

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What has furnished the young plant with the carbon that has been burned in the oxygen of the air? What happens to a bean that grows in the dark? What has been observed in the weight of a bean that has germinated in the dark, compared with the weight of one that has not germinated at all?

mere bean dried in the same fashion before having grown at all. The cotyledons are, in fact, quite dried up and exhausted.

And now let us pass on to another phenomenon. Here is the bean (Fig. 72) I spoke about a few minutes ago, planted at the same time as the former, under similar conditions. Only this one has grown in *full sunlight;* its stem is green; its leaves are broad and healthy.

Were we to dry it, it would weigh *much more* than a simple bean similarly dried.

The shoot of the first bean, that grew in the dark, is *yellow*, and the whole plant, bean, stem, and leaves, *has decreased in weight;* on the contrary, the shoot of the second, that grew in the light, is *green*, and its *weight has increased.*

69. Light causes Increase in Weight.—*So light makes the plant grow* GREEN, *and causes* INCREASE IN WEIGHT. But where has the plant found material wherewith to augment its weight in *solid matter?* I, of course, leave aside the water it drinks. Has it found it in the soil or in the air?

The experiment was made in such a way as to prevent all possibility of the plant's taking any substance from the soil. The flower-pot in which it was planted contained only pounded brick; had it contained pounded china or glass, the result would have been the same. The plant certainly found no nourishment whatever in the flower-pot; it could, moreover, be very easily proved that the weight of the brick-dust has not at all diminished.

Then of course the additional substance found in the plant must have been derived from the air?

Yes, it was. But what has the plant taken from the air? Ah! this is something most marvellous, and that long remained a mystery. The *plant, in order to vegetate, absorbs* CARBONIC ACID, *which is always to be found in the air, decomposes* this carbonic acid, RETAINS and *utilizes the* CARBON, and GIVES BACK THE OXYGEN. I will forthwith relate to you an experiment that proves this statement.

What happens to a bean that grows in the open air? What may be observed on weighing it? Where has the plant found what was necessary to augment its weight in dry material? What has it taken from the air?

70. Absorption of the Carbonic Acid of Air.—In the course of the last century, an English chemist named Priestley placed two mice under a glass shade; naturally, after a certain length of time they both died of asphyxia, having used up all the oxygen of the air under the shade, and of course emitted carbonic acid. Priestley then conceived the idea, for what reason I cannot tell, of putting under the same shade, into the very air which had proved fatal to the poor mice, a small plant with healthy green leaves. Strange to say, *the plant* not only *did not die*, but even appeared to prosper. This result was certainly very interesting; but the most astonishing part of the story is yet to come. Some days afterwards, Priestley removed the plant and put another mouse in its stead. Now this one lived where the others had died; it died only in the ordinary lapse of time,—that is to say, after having consumed all the oxygen; then of course it was asphyxiated like the others. This proves that the plant had *purified* and rendered *respirable* the air that had been tainted and made impure by animals.

Great was Priestley's astonishment; and no wonder. So much the greater was it in those days, when but little was known of the composition of air, or of either carbonic acid or oxygen. All this must have appeared very strange at that time.

At the present day it is quite plain, thanks to chemistry. It is known, as I have told you, *that plants absorb carbonic acid, and decompose it in order to live upon the carbon, which they retain, while they reject the oxygen.* We are thus enabled to explain Priestley's experiment with perfect ease and precision. The mice had consumed all the oxygen of the air under the shade, they also tainted this air with carbonic acid, the product of their respiratory oxidation: an animal could no longer live therein. The plant *absorbed the carbonic acid, retained the carbon, and restored the oxygen;* so that the air became once more fit for breathing.

71. Action of Light on the Green Parts of Plants.—Upon close examination it was seen that two conditions were requisite before the plant could accomplish this process.

1st. THAT THE PLANT BE GREEN, for only the green parts

are capable of thus decomposing carbonic acid; 2d. *That the plant should be exposed to* SUNSHINE, or at least to SUN-LIGHT. Under these conditions the rapidity of the decomposition corresponds to the intensity of the light; it ceases completely in darkness.

72. Experiment.—I undertook to prove to you all I have just stated, so we will now proceed to make a simple experiment. Here is a large vessel of clear white glass (Fig. 73). I filled it at the hydrant, and brought it here a few hours ago, so that the water might not be too cold. One of you go to the old water-cask at the bottom of the garden and bring me some of those long green filaments which grow on its edges, and which I may tell you are called *confervæ*. That is right. See, I hang them on the edge of the vessel, allowing them to float in the water.

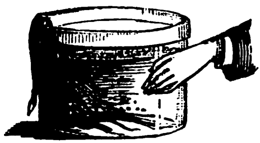

FIG. 73.—Under the influence of light the green *confervæ* have decomposed the carbonic acid of the water, taken up the carbon, and set at liberty the oxygen.

We are in the shade here; let us carry our precious dish into *full sunshine* and wait a little. See now how many little bubbles of gas appear on the green wavy threads. If we shake the vessel gently they will get loose and rise to the surface. *This gas is pure oxygen, which the green plant, under the influence of light, has formed by decomposing the carbonic acid that exists in the water;* for carbonic acid is to be found in water as well as in air.

Now, we will carefully shake the confervæ, so as to detach all the bubbles, then we will cover the glass vessel with this thick box so as to put the whole thing in complete darkness. In a few hours we will lift it off again, and *we shall see that no new bubbles of oxygen will have been formed, because the plant will have remained in the dark.*

Had I had time to go to the river-side to fetch you an aquatic plant called *Potamogeton*, you would have seen the

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What conditions are necessary to enable a plant to decompose the carbonic acid of the air and to restore the oxygen?

same phenomenon, but in much greater intensity. Under the influence of light, this plant discharges oxygen with such rapidity that with a funnel I should have been able to gather a sufficient quantity of it to fill a tube (Fig. 74), and we might have relighted a match with the gas as we did in our chemistry lesson. We may do so at some future day.

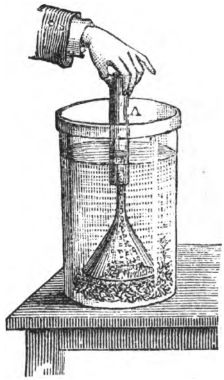

FIG. 74.—*Potamogeton* discharges oxygen in abundance.

Thus *two conditions are necessary for the purification of air* by plant life, GREEN SUBSTANCE and LIGHT.

73. Parts of Plants that are not Green.—But, you may inquire, what happens to the plants that are not green, and what happens when there is no light, during the night, for instance, to plants that are green?

That can be easily explained. Plants that are not green, such as *mushrooms*, or the parts that are NOT GREEN in ordinary plants,—viz., the *flowers*, *fruit*, *roots*, etc.,—behave toward the air EXACTLY THE SAME AS ANIMALS: *they burn—or, if you like it better, they consume—the oxygen of air, and they give out carbonic acid*, and that whether they be in light or in darkness.

As for the GREEN parts, *they remain inactive during darkness.*

74. Recapitulation.—After all I have been telling you, I should like some one to prove that he has properly understood me. Could you do so? How does a green plant act in the daytime?—"It purifies the air, it *takes in the carbon of carbonic acid and rejects the oxygen.*"—Well, can you tell me what particular parts of the plant are at work in this operation?—"Its green leaves, and the green parts generally."

What, as regards the air, is the behavior of plants that are not green, such as mushrooms, or of the parts that are not green in ordinary plants? What do the green parts do during the night?

—Exactly so; now the roots and bulk of the stem, how are they engaged whilst the green parts are at work?—"I think they act as animals do: *they absorb the oxygen* and *exhale carbonic acid.*"—That is quite right.

Thus, at the same time, in the same plant, two opposite phenomena take place: production of carbonic acid by the parts that are not green, and consumption of carbonic acid by those that are green. Only, the latter activity being very much more powerful than the former, the plant not only does not increase the proportion of carbonic acid in the air, but consumes what it finds there.

75. The Real Nature of the Absorption of Carbonic Acid.—The expression "respiration of plants," as you will find it in many books, is, then, quite erroneous when applied to the decomposition of carbonic acid absorbed from air: True, those parts of the plants that are not green breathe like animals, but the decomposition of the carbonic acid by the green parts *is quite the reverse of respiration*, and bears a much closer resemblance to DIGESTION.

The word digestion applied to plants seems to afford you some amusement: why so, pray?—"Because plants have no stomachs."—If that is your only reason, it has but little value; for there are members of the animal kingdom whose organization is so very simple that they are not even provided with a digestive canal, yet they are able to digest the suitable substances that come in contact with their bodies; all the surface of their body thus acting as a digestive organ. But tell me, why do people digest?—"In order to nourish the body."—Well, then, when the plant decomposes carbonic acid, don't you think it *nourishes itself upon the carbon* it retains for its own use? If you study the composition of the plant, you will find that carbon forms about the half of its substance. Well, it obtains this carbon from the carbonic acid of the air that surrounds it, and that dissolved in the water which bathes its roots and which it sucks up into its body. *You see the word digestion is quite proper*, and comes nearer the truth than the word respiration.

Why is the absorption of carbonic acid by the green parts of plants a digestive process?

And this is why the bean I showed you a little while ago, that had breakfasted on sunlight, had prospered and grown heavier. It is for this reason and in this manner that all green plants around us grow (Fig. 75). All day long they are busy decomposing carbonic acid, in order to lay in provision of carbon and add to their height and their weight. Through the dark hours of night they take rest, and even use up a little of their store of carbon laid by in the daytime, and thus they exhale carbonic acid. You see all this is very simple indeed.

FIG. 75.—The green parts decompose the carbonic acid of the air, retain the carbon, and give up the oxygen.

76. Winter.—I see you have a question to ask.—"Please, in winter, when the leaves have fallen off, what happens?"—That is a very good question. Well, in winter things go on in the same way as during the night. The plant breathes, and consumes day and night the carbon it had gathered in during its green time, in the long summer days. So at the end of winter the plant weighs less (in dry material, of course) than at the beginning. *It has lived on its store.* If winter were to last forever the plants would all perish of hunger.

Has anybody anything else to ask?—"Please, of what use are the roots, since it is the leaves that nourish the plant? Why are they watered? Why are they manured?"—Oh! these are a good many questions at once. But be patient, they will all be answered.

77. Part played by Roots.—Of what use are roots? In the first place, they support the plant, for it would be unable to stand against the wind without their aid. You can easily understand this, so I need say no more on the subject.

What happens in winter, when the leaves have fallen? Give a proof of it. What is the use of roots?

Why do we water plants? Let us try to reason a little. A plant is like a sponge full of water. If cut down, it rapidly dries up in the air and sunshine. It would dry up in like manner while standing, did not its roots plunge down into a soil more or less moist and suck up into its body the necessary supply of water. Hence when the soil is dry it requires to be watered.

Things go on in the following manner: the leaves that the sun threatens to dry up suck water from the branch on which they grow; the branch draws up its share from the stem, and the stem from the root, which in its turn renews its provision from the soil.

FIG. 76.—The roots transmit to the plant water and all the matters that can be drawn from the soil.

The moisture is then sucked up by the evaporation of the leaves; it rises through very fine tubes or vessels contained in the wood.

Thus you see that plants should not be watered at random. It is necessary to consider the degree of heat, the state of the air or of the wind, the area of the plant exposed to evaporation, and also its mode of living, for while some plants require great quantities of water, others need but little. These last generally have thick fleshy leaves that enable them to hold a certain quantity of water in reserve, or else they are provided with roots that penetrate deep into the soil and reach places that are always damp.

78. Absorption of Nutritive Matter in the Soil.—The water that the roots thus obtain from the soil is not pure distilled water: it has dissolved all that could be dissolved in the earth through which it has filtered, and the roots absorb these substances along with the water they suck up.

This is most important, for vegetable matter contains not only carbon, hydrogen, and oxygen (the constituents of water) and water, but also *nitrogen*, although in less quantity

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What other services do roots render to plants? Describe what takes place. Show how the water rises from the roots to all parts of the tree. Is pure water drawn up by the roots? What else is there in vegetable matter besides water and carbon?

than is found in the bodies of animals. It also contains *phosphorus*, *potash*, *lime*, *salts*, *silica*, *iron*, etc.

All these the plants find in the water which their leaves inhale and their roots absorb.

79. Necessity of Manure.—You can easily believe that, by continually dissolving the different substances of which I have been speaking, water at length impoverishes the soil, so that the necessary food of the plant is no more to be found therein. In nature things go on quite smoothly all alone. When a plant has grown, and when by its roots it has absorbed all the nourishment its soil could afford, it *dies*, falls, rots on the place it had exhausted, and *returns to the ground the matter it had absorbed.* But when a plant grows in cultivated land, things are altogether different: we cut down the plant and *carry it away;* thus it happens with cereals, with fodder; we cut them for use, instead of allowing them to fall down and die like wild plants. And the poor earth, who will repay it for all it has given to the corn, to the hay? Naturally, it becomes exhausted, and, after bearing two or three crops of corn, has nothing more to give to feed corn, which refuses to grow there: *what has been taken away must then be given back*, in some shape or other.

This is why *manure* is indispensable. All plants have need of nitrogen: so farm-yard manure, which contains a great deal of it, is useful to all of them. But it is a very remarkable fact that all plants do not absorb exactly similar substances; naturally, it is necessary to give back to the soil precisely the substance the plant has absorbed. Thus, the grape-vine contains considerable potash; therefore wood ash is excellent manure for vineyards, because it is rich in potash. Wheat contains phosphorus; hence phosphates, or crushed bones, will greatly facilitate its vegetation. All this is plain enough and easy to understand as a principle.

But I must add something further. I said a minute ago, "When a plant has grown, it dies, rots on the place it occupied, and gives back to the earth what it took from it." This

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By what agency is all this furnished? Why does farm-yard manure suit all plants? How ought the grape-vine to be nourished? What is the nourishment that suits wheat?

is quite true, but it is not the whole truth. The plant yields to the earth not only what it took from the soil, but also what it took from the air; that is to say, all its carbon, and also its nitrogen, which is extracted from the air by a very curious and intricate process. You can thus understand how it is that *exhausted land left to rest*, as people used to term it, becomes fertile again, by the sole action of the weeds that spring up upon it. The land is as it were manured by nature. Practically speaking, however, it is generally more profitable to put manure on the land, so as to enable it to be continuously yielding produce.

80. Plants produce what Animals consume.—You now have a pretty accurate idea as to how plants live, and you can understand why their existence is indispensable to animals. Plants, by the action of light on their green substance, take in carbon from the air; by means of their roots they take the hydrogen and oxygen from the water they find in the soil, nitrogen from the nitrogenous mineral compounds, and with all these *they make the organic matter that is necessary for the life of animals*, such as the starchy matter, sugar, oil, and the nitrogenous constituent of the grain (gluten). *The animal by itself cannot make anything with which to support life; it is capable only of constantly transforming*, of consuming, and of restoring to the state of water, carbonic acid, and nitrogenous mineral compounds, the organic matter which the plant had produced with these very same substances.

Thus the animal eats the plant (herbivorous), or else it eats the animal that has already fed on plants (carnivorous): be this as it may, the animal lives on the plant.

Again, when the animal dies, the plant finds food in its dead body; and even during the life of the beast, the plant feeds on the carbonic acid rejected in animal respiration as well as on the waste products of animal alimentation. Thus the animal feeds on the plant, and the plant on the animal, with the help of sunshine and air.

81. Sunlight indispensable to Life.—The first indispen-

What do plants do with all they absorb? Can an animal make anything to support life? On what does an animal live? What services does the animal render the plant? How may these mutual services be expressed?

sable requisite to life is the SUN. Were the sun to be extinguished, the green parts of the plant could no longer fulfil their functions; they would even disappear, as is the case when a plant grows in darkness. Hence there would be no formation of new vegetable matter; the store of food for animals would soon be exhausted, and they would die. So it may be truly said that all life depends on the sun; for were its heat or its light to fail, nothing living could exist on the face of the earth.

82. Subjects of Study necessarily left aside.—I have now told you all that the limits of this course of lessons upon

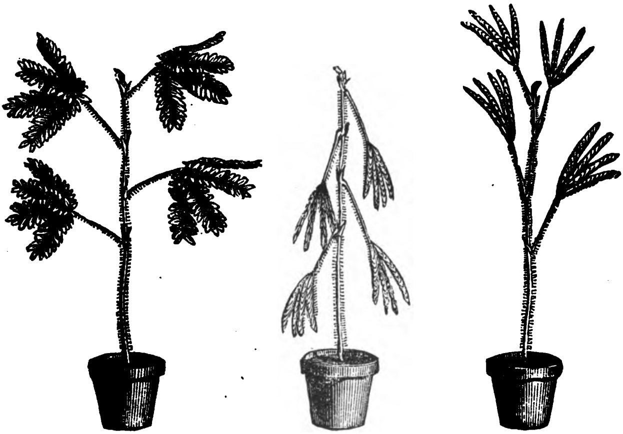

FIG. 77.—Sensitive plant: after a shock; sleeping at midnight.

vegetable physiology will admit. Many more very interesting problems still remain to be studied. You have not yet learned about the substances formed by green leaves; how the sugar contained in the leaves—in the grape-vine or in the wheat-stalk, for instance—quits these organs and goes to form the sugar of the grape or the starchy matter of the grain of wheat; how it is that during the first part of its existence

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What would become of plants and of life generally if the sun were extinguished?

the beet stores up in its root the sugar it will require during the second, when it will bear flowers and seeds; how the different juices circulate through plants, and what the *sap* really is; all about the *bud*, and how it can live when separated from the plant that bore it, and can be transplanted by *grafting* or by *slips;* how the pollen and the ovule come in contact with each other, as is necessary for the formation of the seed; how some plants have one appearance in the daytime and another after nightfall, either as regards their leaves, as with the acacia, or their flowers, as with the field daisy; how some plants *sleep;* how others have parts that seem to have feeling, and move when touched, as the sensitive plant (Fig. 77), or the stamina of certain flowers.

You see much remains to be learned. But the great thing is to understand perfectly how plants produce organic matter, and I hope you all understand that now.

SUMMARY.—VEGETABLE PHYSIOLOGY.

1. **Germination** (p. 71).—MOISTURE is required for germination.
2. A certain degree of HEAT is likewise necessary.
3. It is also indispensable that the seed have access to THE AIR.
4. The part of the air necessary for the growth of the plant is OXYGEN. This the plant absorbs, breathes, and burns, giving back *carbonic acid* just as an animal would do.
5. To be thus able to burn or consume oxygen, *carbon* is necessary; this the young plant finds in its cotyledons.
6. If the seed germinates in the dark, the germination will take place exclusively at the expense of the carbon contained in the cotyledons; the plant will grow up yellow, and if weighed after drying will be found to be lighter than a mere seed similarly dried without having sprouted.
7. Thus in the dark the plant springs up yellow, and its weight diminishes.
8. If, on the contrary, the plant is grown in daylight, its shoot will be green; when dried it will be found to weigh more than a seed dried without having germinated.
9. When the plant has exhausted the carbon contained in its cotyledons, or even before this is quite exhausted, it will absorb and decompose the carbonic acid contained in the air, retaining the carbon and giving back the oxygen.
10. **The Action of Light on the Green Parts of Plants** (p. 75).—Plants purify the air: in order to accomplish this purification the following two conditions are indispensable: 1. The plant must be *green*, as the green parts alone decompose carbonic acid; 2. The plant must be exposed to sunlight.
11. In the dark, the decomposition of carbonic acid ceases completely.

12. Parts of Plants that are not Green (p. 77).—The parts of plants that are not green, such as the flowers, fruits, roots, act, as regards the air, just as animals do: *they consume oxygen and exhale carbonic acid.*

13. Digestion of Plants (p. 78).—Those parts of plants that are not clad in green *breathe* like animals; but the decomposition of carbonic acid by the green parts is rather a *digestive* than a respiratory act.

14. The plant feeds on the *carbon* it retains, just as animals feed on the carbon they find in their food.

15. In winter, when the plants have lost their leaves, and consequently have no green parts, they live on the store of carbon laid in during the summer.

16. Part played by the Roots (p. 79).—The roots, in the first place, sustain the plant, and keep it from being overturned; but this is not the only part they play.

17. The water of the soil, sucked up to replace the water evaporated by the leaves, contains several substances: nitrates, phosphorus, potash, lime, silica, iron. These substances are absorbed by the plant.

18. Use of Manure (p. 81).—After a certain length of time, however, all these substances are exhausted by the plants; it is in order to replenish the earth with them that manure is necessary.

19. Plants produce what Animals consume (p. 82).—With the help of their green substance and light plants extract from the air its carbon, from the soil the hydrogen and oxygen of water, nitrogen from the nitrogenous mineral compounds, and with all these substances they make the organic matter necessary for animal life: starchy matter, sugar, oil, gluten.

20. An animal is incapable of producing anything to support life; it can but restore to the state of water, carbonic acid, or nitrogenous mineral compounds the organic matter which the plant had produced with these very substances.

21. *Sunlight* is indispensable to all this.

SUBJECTS FOR COMPOSITION.

1st Composition (p. 71).—How does a plant obtain its carbon during the process of germination? Difference between a bean that has sprung up and grown in the dark and a bean that has sprung up and grown in the light. How does a plant breathe during the process of vegetation?

2d Composition (p. 75).—Experiment of Priestley proving the absorption of the carbonic acid of air by green plants. Experiments of like description with *confervæ*, etc.

3d Composition (p. 76).—The action of the green parts of plants. How do these green parts act during the night? How do the leafless trees live throughout winter?

4th Composition (p. 78).—Why are we justified in saying that the absorption by plants of the carbonic acid of air is a digestion rather than a respiration?

5th Composition (pp. 79 and 81).—The function of roots. Necessity of manure.

GLOSSARY.

Abdomen, the cavity of the body containing the liver, stomach, and intestines.

Aerial, living in air.

Aggressive, attacking without having been provoked.

Air-pump, a pump by which air may be removed from any vessel.

Algeria, a French colony in the north of Africa.

Aliment, food.

Alloy, a combination of metals by melting them together.

Alpine, of the Alps.

Alps, a chain of mountains that separates France from Switzerland and Italy.

Altitude, the height of a place above the level of the sea.

Alveoli, the sockets of the teeth (singular, *alveolus*).

Amphibia, animals that live sometimes in water, sometimes in air.

Anatomist, one who studies the organism of the body, whether it be the human body or that of any animal.

Annuals, plants that live only one year.

Annulates, animals whose bodies are composed of a series of ring-shaped divisions.

Aquatic, living in water.

Arable, capable of being cultivated:—applied to soil.

Artery, a blood-vessel carrying blood from the heart.

Articulation, a joint.

Artificial, produced by art, or man's industry:—the contrary of what has been produced direclly by nature.

Asia Minor, a name given by the ancients to that part of Asia which lies to the south of the Black Sea, and which is also called Turkey in Asia.

Asphyxia, suffocation, smothering.

Atmosphere, air.

Auditory, concerning the sense of hearing.

Axilla, the armpit; also the point at which a leaf or the stalk of a leaf joins the stem.

Baltic, a sea in the north of Europe. It lies between Russia and Sweden, and to the north of Germany.

Barometer, an instrument for measuring the pressure of the atmosphere.

Bed (of a river), the hollow or channel in which a river runs.

Beer, the product of the fermentation of steeped barley and hops.

Biennials, plants that live during only two years.

Bimana, two-handed animal, man.

Bomb-shell, a hollow ball of metal, filled with powder, and fired from a short cannon called a mortar.

Borneo, an island of Oceanica.

Botanist, one who studies plants.

Botany, the description and classification of plants.

Bow, the instrument used to sound a fiddle.

Brass, an alloy of copper and tin.

Bronchia, small tubes of the lungs.

Burrow, to hollow out.

Calcareous, chalky.

Calcination, the act of reducing to powder by heat.

Calcine, to reduce to powder by heat.

Calyx, all the sepals or green leaves at the lower part of a flower taken together.

Carapace, a sort of shell which protects and encloses the bodies of tortoises and some reptiles, etc.

Carnivorous, feeding upon flesh.

Carpus, the wrist-bone.

Cartilage, gristle, unhardened bone.

Cavity, a hollow.

Century, a period of a hundred years.

Cereals, a name given to a family of plants, such as wheat, barley, and oats, whose seeds, ground into flour, are food for mankind.

Chio, an island in the Mediterranean, situated to the southwest of Asia Minor. Chio was partly destroyed in 1881 by an earthquake.

Circumference, the line that bounds the space of a circle.

Clavicle, the collar-bone.

Coagulation, the thickening or hardening of a liquid.

Colony, properly, a group of persons settled down in a foreign country. The term is applied in natural history to animals that live in groups.

Combustion, the union of a substance with the oxygen of the air.

Compressed, pressed together so as to occupy less space.

Concave, hollow, like the inner surface of a round body. A concave lens is a piece of glass slightly hollow on both sides.

Conical, shaped like a cone. A sugar-loaf is conical.

Convex, rising into a rounded form. A convex lens is a piece of glass slightly swelling out on both sides towards the centre.

Cornea, the clear part at the front of the eye.

Corolla, all the colored leaves of a flower taken together.

Cotyledons, the seed-leaves surrounding the germ of a plant.

Crustacean, an aquatic annulate, such as the lobster.

Cuvier, a celebrated French naturalist (1769–1832), the creator of palæontology, or the science which treats of beings that have disappeared from the earth.

Deglutition, swallowing.

Denmark, a country in the north of Europe.

Derm, the inner layer of the skin.

Deviate, to turn aside from a straight line.

Diameter, a straight line passing through the centre of a circle and terminated at both ends by the circumference.

Diaphragm, the membrane which separates the thorax, containing the heart and lungs, from the abdomen, containing the liver, stomach, and intestines.

Distil, to evaporate and subsequently condense a liquid.

Domesticate, to make familiar; to tame wild animals so as to render them serviceable to mankind.

Ebullition, the changing of a liquid to a gas, with escape of bubbles of vapor all through the liquid.

Effervescence, a sort of boiling up caused by the escape of gas from a liquid.

Elasticity, the property of returning to a previous form, the cause of the alteration being withdrawn.

Emission, the act of giving out or throwing forth.

Epiderm, the outer layer of the skin.

Evaporation, the change of a liquid to a gas quietly and without escape of bubbles.

Expand, to enlarge in bulk; to spread out.

Expansion, increase of size.

Farinaceous, starchy.

Femur, the bone of the thigh.

Fermentation, a decomposition which takes place under the combined influence of warmth, air, and moisture, the elements of the substances acted on afterwards reuniting into a new combination.

Fifth (in music), a musical interval of five notes following one another, the two extremes being included.

Fleshy, well furnished with flesh. The term is used in speech about fruit as well as about real flesh. Pears, peaches, etc., are said to be fleshy.

Flexor, a muscle that draws bones together or bends a joint.

Fontainebleau, a town in the centre of France.

Fossils, the remains of ancient animals embedded in rocks.

Friable, easily reduced to powder. Calcined substances are friable.

Fructification, the act of bearing fruit.

Fructify, to bear fruit.

Gaboon, a French colonial establishment on the west coast of Africa.

Gallery, a passage or corridor:—often applied to passages in mines.

Germ, that part of the seed which produces the new plant.

Germination, the act of sprouting. A seed that germinates is a seed that begins to shoot forth, to grow.

Glass (magnifying), an instrument employed to make things appear larger and allow people to study minute objects.

Greenland, a Danish possession in North America, to a great extent covered with ice-fields.

Guinea, a country on the west coast of Africa.

Gum arabic, a vegetable juice, which oozes out of some trees and becomes solid by contact with the air.

Gustatory, concerning the sense of taste.

Hemispheres, half spheres. A sphere is a round globe-shaped body. People speak of the terrestrial hemispheres, the world being considered as a globe divided into two equal parts.

Herbivorous, feeding upon plants alone:—applied to grazing animals.

Hibernation, the state of animals that sleep throughout winter.

Horizontal, parallel to the horizon. The surface of still water is horizontal.

Hot-house, a house with glass roof, artificially heated, and arranged for growing plants that require more than ordinary heat.

Humerus, the bone of the upper arm.

Immemorial, beyond memory; so far back that no recollection has remained.

Infusoria, minute animals that live in stagnant water.

Insect, a six-legged annulate.

Insectivorous, feeding on insects.

Internal, inward; interior:—opposed to *outward*, or *external*.

Intestine, the gut.

Invertebrates, animals that have no vertebral column, or bones properly so called.

Iris, the colored ring which surrounds the black spot in the eye. The iris is a muscle.

Keel, the lowest timber of a ship, extending from end to end all along the bottom of the vessel.

Kneaded, wrought and pressed into a uniform mass.

Larvæ, insects in their "masked" or first state of existence (singular, *larva*).

Larynx, the upper part of the windpipe, called also the throat, and contributing to the formation of the voice; Adam's apple.

Lava, melted stone thrown from volcanoes.

Ligaments, bands that hold bones together at the joints.

Limestone, a calcareous stone much used for building.

Linnæus, a celebrated Swedish naturalist (1707–1778), author of the classification of plants.

Liquefied, rendered liquid.

Loadstone, an ore of iron which has the power of attracting iron. It is also called *natural magnet*.

Luminous, giving light.

Madagascar, a large island in the Indian Ocean, to the east of Africa.

Mammalia, animals that feed their offspring with milk (from *mamma*, the Latin word for breast).

Manure, substance added to the soil to increase its fertility.

Marine, concerning the sea; living in, or close to, the sea.

Martinique, one of the West India islands.

Masticate, to chew.

Mastication, the act of chewing.

Membrane, a film; a sort of outspread skin.

Mercury, a metal:—called also *quicksilver*. The only metal that remains liquid at ordinary temperatures.

Metacarpus, the bones of the hand, not including the fingers.

Metatarsus, the bones of the foot, not including the heel or the toes.

Microscope, an optical instrument of much more complicated construction than the magnifying-glass, and of greater magnifying power.

Milan, a city of Italy.

Mine, a pit or excavation in the earth, from which ores or other minerals, such as coal, etc., are obtained by digging.

Molar, a double tooth or grinder.

Mollusks, animals whose bodies are soft and pulpy.

Mortal, capable of causing death.

Moulded, shaped or fashioned in a mould. The mould is an object hollowed out so as to give a certain shape to whatever is run or kneaded into it.

Movable, capable of being moved.

Muscle, the fleshy substance that by contracting moves the bones on their joints.

Naples, one of the principal cities of Italy.

Naturalist, one who studies, or is versed in, natural history.

Newfoundland, a large island in the Atlantic Ocean, to the northeast of North America.

New Zealand, an island of Oceanica.

Nitrogenous, containing nitrogen.

Nocturnal, of the night. Nocturnal birds are birds that fly abroad during the night only.

Octave, a musical interval of eight consecutive notes.

Œsophagus, the gullet, or tube leading from the mouth to the stomach.

Oil, a name given to all greasy substances which retain their liquid state at ordinary temperatures.

Olfactory, concerning the sense of smell.

Omnivorous, living on both vegetables and flesh.

Opaque, not transparent; not capable of being seen through.

Ovary, the seed-vessel of a flower.

Ovules, the germs of seeds.

Pelvis, the hip-bones supporting the internal organs.

Perennials, plants that remain in life for several years.

Petals, the colored leaves of a flower.

Petiole, the stalk of a leaf.

Phalanges, the bones of the fingers and toes.

Physiologist, one who studies the science that treats of the phenomena of life,—or the functions of the organs in animals or plants.

Pilfering, stealing.

Pistil, the ovary and styles of a flower.

Poland, a former European state, annexed to Russia.

Pollen, the fine dust that grows on the stamens of flowers and is necessary for the fruitfulness of the seed.

Prey, spoil; that which is, or may be, seized by violence, to be devoured.

Priestley, a learned English chemist and experimentalist (1733–1804).

Protuberance, something that swells or bulges out.

Pulse, the throbs caused by the motion of the blood in the arteries. These throbs are easily felt at the wrist or the temples, because in these places the arteries lie very near the skin.

Pupil, the dark spot in the centre of the eye.

Putrefaction, rottenness; the decomposition that takes place in all dead organic bodies.

Pyrenees, the chain of mountains that separates France from Spain.

Quadrumana, monkeys.

Quadrupeds, four-footed animals.

Radiates, animals having a central mouth, around which the body forms a star-shaped figure.

Radius, one of the two bones of the forearm.

Reef, a chain of rocks lying at or under the surface of the sea.

Reflection, a throwing back.

Refraction, a bending.

Reptiles, cold-blooded, aerial vertebrates, whose bodies are covered with false scales. Tortoises, serpents, and lizards are reptiles.

Respiration, breathing.

Retina, an enlargement of the nerve of sight which receives the images of objects thrown on it by the crystalline lens.

Rhone, a river which rises in Switzerland, runs through the lake of Geneva, and, continuing its course through France, falls into the Mediterranean Sea.

Sacrum, the lower part of the backbone.

Saliva, spittle.

Scale (musical), a series of harmonic sounds arranged in their natural order.

Scapula, the shoulder-blade.

Sepals, the green leaves that form the under part of a flower.

Siberia, a country in the north of Asia.

Silicious, sandy.

Slip, a twig taken from a plant and intended to be planted, so as to take root and thus furnish a new plant.

Sonorous, sounding.

Spider, an eight-footed annulate.

Spindle, a small instrument used for spinning. It is a piece of wood, rounded like the bar of a chair, swelling out towards the middle, and tapering off at each end.

Spitzbergen, a group of islands in the Arctic Ocean, to the north of Lapland.

Stamens, little rods in the centre of a flower, bearing a yellow dust.

Starch, a substance extracted from many plants, particularly from wheat. Starch mixed with water is used to stiffen and dress linen.

Sternum, the breast-bone.

Structure, the mode of composition of a body; the disposition of its different parts in relation to one another.

Styles, little projections from the ovary of a flower.

Subjugated, conquered; made subject to.

Submerged, entirely covered by water.

Sucker, an apparatus that acts upon the same principle as the small disk of steeped leather with which school-boys lift up stones. Some animals use these suckers in order to lay hold of their prey, or to adhere to anything.

Superposition, the state of being superposed,—that is, placed upon or above something else.

Tamed, reduced from a wild to a domestic or mild state.

Tarsus, the bones that constitute the heel.

Tendons, the white elastic ends of muscles.

Thermometer, an instrument used to ascertain the degree of heat of any body or that of the surrounding air. This is determined by means of the contraction and expansion of mercury or alcohol in an hermetically-sealed glass tube.

Thorax, the chest.

Tibia, the shin-bone.

Tinder, a substance obtained from a sort of mushroom, and subjected to a chemical process which renders it very easily kindled.

Tinned, lined or overlaid with a coating of tin. Mirrors are lined with a mixture of tin and mercury.

Transverse, crosswise.

Triangular, having the form of a triangle; three-cornered.

Trunk, the prolongation of the elephant's snout.

Twilight, the faint light between sunset and night, also between sunrise and dawn.

Ulna, one of the two bones of the fore-arm.

Valley, a space of low-lying ground between two or more hills or mountains.

Vegetation, the growth of the parts that constitute the plant.

Vein, a blood-vessel carrying blood to the heart.

Ventilate, to renew the air; to cause a fresh supply of air to pass through a room, etc.

Vertebra (plural, *vertebræ*), one of the bones that compose the spinal column.

Vertebral column, the spinal column; the backbone.

Vertebrates, animals provided with vertebræ.

Vertical, pointing to the centre of the earth.

Volta, a celebrated Italian who studied natural philosophy and invented many instruments for his experimentation. The most celebrated is the electric pile, which still bears his name.

Wieliczka, a town of Poland.

Wine, an alcoholic liquor obtained by the fermentation of the juice of grapes.

Zoophytes, animals which have a plant-like appearance, such as coral.

THE END.

E B Edwards

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